AFIT/GEE/ENV/93S-16

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A FEASIBILITY STUDY OF BURNING WASTE PAPER IN COAL-FIRED BOILERS ON AIR FORCE INSTALLATIONS

THESIS

Kenneth P. Smith, Captain, USAF

AFIT/GEE/ENV/93S-16

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

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THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of Master of Science

In Engineering and Environmental Management

Kenneth P. Smith, B.S.E.E.

Captain, USAF

September 1993

Preface

The use of waste paper derived fuel in coal-fired boilers may be one way to help solve the current solid waste disposal and air emission problems facing not only the Air Force but the entire country. This thesis is designed to assist the Air Force in determining if waste paper is both a technically acceptable and an economically feasible alternative fuel for coal-fired boilers.

I have had a great deal of assistance from many gracious people in completing this thesis. My advisor, Captain Jim Aldrich, was of invaluable assistance in guiding and motivating me throughout the research process. My reader, Major Jerry Bowman, offered a great deal of excellent advice to ensure a well researched and developed effort. The entire Engineering and Environmental Management staff provided me with the necessary education and knowledge needed to complete this effort. Outside of AFIT, I received a great deal of assistance from members of the Wright-Patterson AFB Civil Engineering Squadron, including Don Roth, CMSgt John Solomon, John Gibson, and Tony Day. I would also like to thank Carl Holley, President of Ferro-Tech, Incorporated, for the invaluable assistance he provided me in the area of waste paper briquetting.

My final and most important thanks goes to my friends and family for without their help I would have never made it through this long, tough effort. Thanks.

Table of Contents

Page

Preface ii

List of Figures vi

List of Tables vii

Abstract viii

I. Introduction 1

General Issue 1

Municipal Solid Waste 1
Paper Recycling 4
Clean Air Act Compliance 6

Research Objective 7
Investigative Questions 7

Technical Acceptability 7
Economic Feasibility 7

Scope of Research 8
Overview of Research 9

II. Literature Review 11

Overview 11
Waste Paper 12

Paper Recycling 12
Paper Composition 15

Pulp 16
Paper Fillers 17
Paper Coatings 17
Paper Dyes 18
Printing Inks 18

Combustion Characteristics 19

Coal-Fired Boilers 21

Travelling-Grate Spreader Stoker Boilers 21

Coal Handling Systems 26
Fuel Characteristics 28
Combustion Temperature Range 32
Emission Controls 32

Applicable Laws and Regulations 38

Clean Air Act 38

CAA of 1990 Title IV: Acid Rain . . 39
CAA of 1990 New Source Performance Standards 40
CAA of 1990 Hazardous Air Pollutants 40
CAA of 1990 Solid Waste Combustion 41
CAA Title V: Permits 41

Ohio Air Permits 42

Resource Conservation and Recovery Act . 43
Air Force Policy Directive 19-4, Pollution Prevention 44

Summary 45

III. Methodology 47

Overview 47
Technical Acceptability 48
Economic Feasibility 50
Summary 52

IV. Evaluation of Technical Acceptability and Economic Feasibility 53

Overview 53
Technical Acceptability 53

Waste Paper Fuel Characteristics 53

Moisture Percentage 54
Volatile Matter Percentage 55
Ash Percentage 56
Ash Fusion Temperature 57
Sulfur Percentage 58
Heat Content 58
Size 59

Waste Paper Agglomeration 60
Applicable Law and Regulation Compliance 63

Clean Air Act Compliance 63

CAA of 1990 Title IV: Acid Rain 63
CAA of 1990 New Source Performance Standards 64
CAA of 1990 Hazardous Air Pollutants 65

CAA of 1990 Solid Waste Combustion 68
CAA of 1990 Title V: Permits . 68

Resource Conservation and Recovery Act 69
Air Force Policy Directive 19-4, Pollution Prevention, Compliance . . 70

Economic Feasibility 70

Economic Analysis 71

Cost Calculations 74

Costs/Savings 75
Life Cycle Cost Analysis . . . 76

Wright-Patterson Air Force Base Case Study 77

Summary 81

V. Conclusions and Recommendations for Further Research 83

Conclusions 83
Recommendations for Further Research 85

Appendix A: Coal Specifications, Wright-Patterson AFB . 87

Appendix B: Toxic Air Pollutants 88

Appendix C: Boiler Permit, Wright-Patterson AFB 93

Bibliography 100

Vita 105

List of Figures

Figure		Page
1.	Projected Number of Operating Municipal Landfills	2
2.	Estimated Percentages of Materials in MSW, by Weight	4
3.	Typical Travelling-Grate Spreader Stoker Boiler	23
4.	Travelling-Grate Spreader Stoker	24
5.	Spreader Stoker Mechanism	25
6.	Coal Handling Equipment, Truck Delivery	26
7.	Coal Handling Equipment, Truck Delivery with Additional Silo Storage	27
8.	Rubber Belt Conveyor for Coal Transport	28
9.	Typical Cyclone Emission Control	34
10.	Electrostatic Precipitator Emission Control	36
11.	Fabric Filter Baghouse Emission Control	37
12.	Waste Paper Briquetting System	61
13.	Roll Briquetter	62

List of Tables

Table		Page
1.	Energy Content of Various Materials	21
2.	Typical Sulfur Percentage in Various Types of Coal	31
3.	Typical Coal Properties	31
4.	Ultimate Analysis of Waste Paper and Coal Fuels	66
5.	Typical Trace Metals in Paper	68
6.	Net Present Value Calculation Results	80

AFIT/GEE/ENV/93S-16

Abstract

This thesis examined the feasibility of using waste paper derived fuel in coal-fired boilers on Air Force installations in an attempt to help solve air pollution and solid waste disposal problems. The implementation of waste paper derived fuel was examined from both a technical acceptability and an economic feasibility viewpoint. The majority of data for this study was obtained through literature reviews and personal interviews.

Waste paper was found to be technically acceptable for use as fuel. However, waste paper has certain characteristics that may create problems during combustion and therefore further research is required. These problems include the possibility of increased nitrous oxide emissions, increased volatile emissions, dioxin and furan emissions, formation of hydrochloric acid, and the presence of heavy metals in emissions and ash.

A life cycle cost model was developed to determine the economic feasibility of implementing waste paper derived fuel. This economic feasibility is dependent upon the answers to the above technical problems, but a case study of waste paper derived fuel at Wright-Patterson AFB showed a sufficient economic benefit to probably compensate for additional costs associated with these technical problems.

The study concluded by recognizing that the Air Force has a unique opportunity to be a leader in implementing the use of waste paper derived fuel, and further research in this area is highly encouraged and strongly justified.

A FEASIBILITY STUDY OF BURNING WASTE PAPER IN COAL-FIRED BOILERS ON AIR FORCE INSTALLATIONS

I. Introduction

General Issue

This section discusses three environmental issues that are currently facing the United States: municipal solid waste, paper recycling, and air pollution. At first glance these issues may not seem to possess any similarities, but when the issues are examined more closely, their relevance becomes evident.

Municipal Solid Waste. The United States currently generates over 160 million tons of municipal solid waste each year, and the amount of waste generated is increasing by 2-4% annually (Chiras, 1991:443). Municipal solid waste (MSW) is solid waste generated by residences; commercial establishments, such as offices and restaurants; and institutions, such as hospitals and schools (U.S. Congress, Office of Technology Assessment, 1989:4).

Even though the amount of waste produced is increasing, the number of landfills in which to place the waste is decreasing. As shown in Figure 1, the Environmental Protection Agency (EPA) estimated that 80 percent of the landfills existing in 1986 would close within the next 20 years (U.S. Congress, Office of Technology Assessment,

1989:3). This problem of insufficient landfill capacity for municipal solid waste is of concern to the Air Force because most bases use local community landfills to dispose of their waste.

The Air Force has issued guidance in their Pollution Prevention Program Action Plan addressing waste disposal. The specific guidelines are based on 1992 baseline data and require all bases to reduce MSW disposal by 10% by the end of 1993 and by 50% by the end of 1997 (Department of the Air Force, Air Force Pollution Prevention Program, 1993:4).

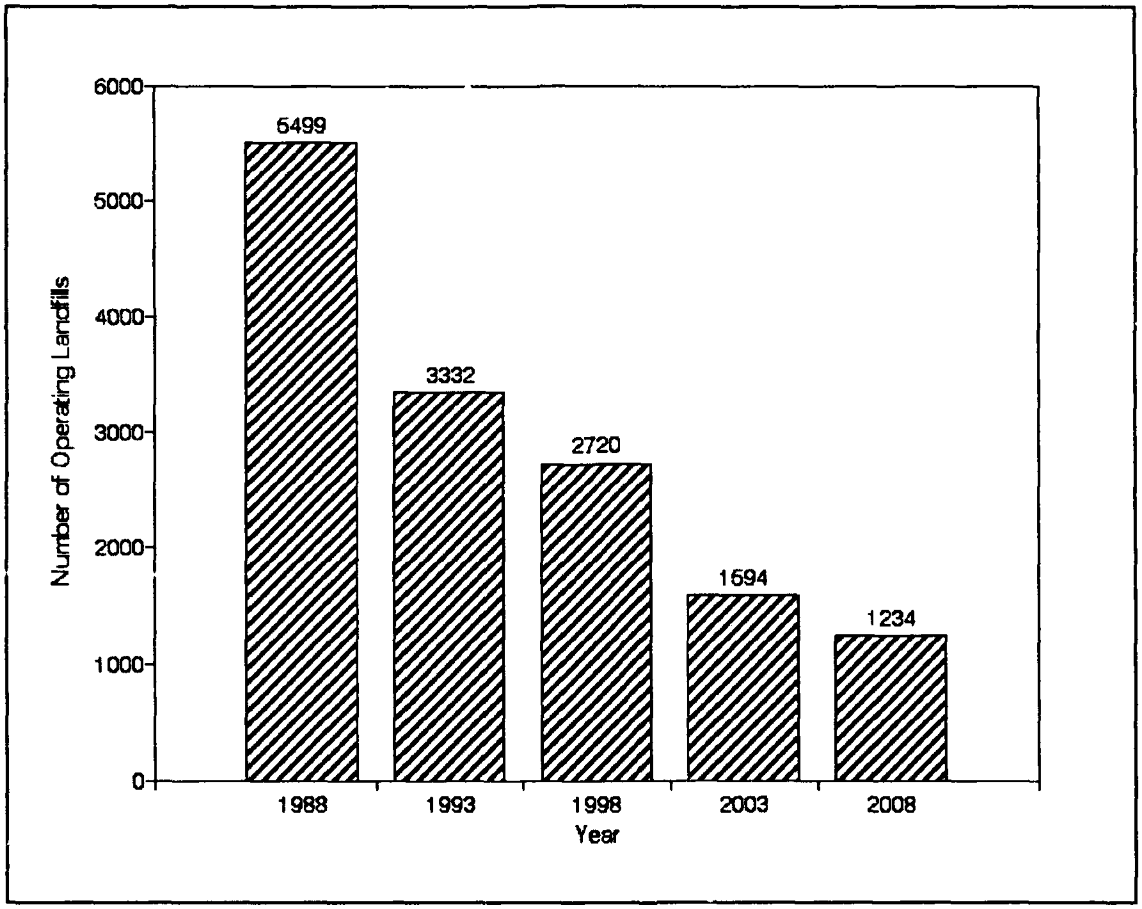

Figure 1. Projected Number of Operating Municipal Landfills (U.S. Congress, Office of Technology Assessment, 1989:273)

Two of the alternatives to landfill disposal, incineration and recycling, have arisen in an attempt to alleviate the problems of increasing MSW volume and insufficient landfill space. According to the EPA, approximately 13 percent of the total MSW is recycled (Porter, 1991:1542). Of the remaining MSW, 10 percent is incinerated and 77 percent is placed in landfills (U.S. Congress, Office of Technology Assessment, 1989:6). This large percentage of MSW still being disposed of in landfills indicates the two current alternatives are not solving the problem.

Incineration of solid waste has yet to win over public support. Even though the combustion of solid waste may be technically and environmentally sound, it has received great public opposition based on perceived risks associated with airborne emissions and solid ash by-products (Tillman, 1991:223).

Recycling is the collection and return of previously used items to industry where the items are used as a substitute for raw materials in the production of new products. The need for increased recycling is one of the few areas on which almost all environmentalists agree (Porter, 1991:1542). The composition of MSW is one reason that recycling can be an effective solution to the waste problem. Figure 2 shows the percentages of materials that compose the entire MSW stream. Paper and paper board make up the largest percentage of MSW and both can be recycled.

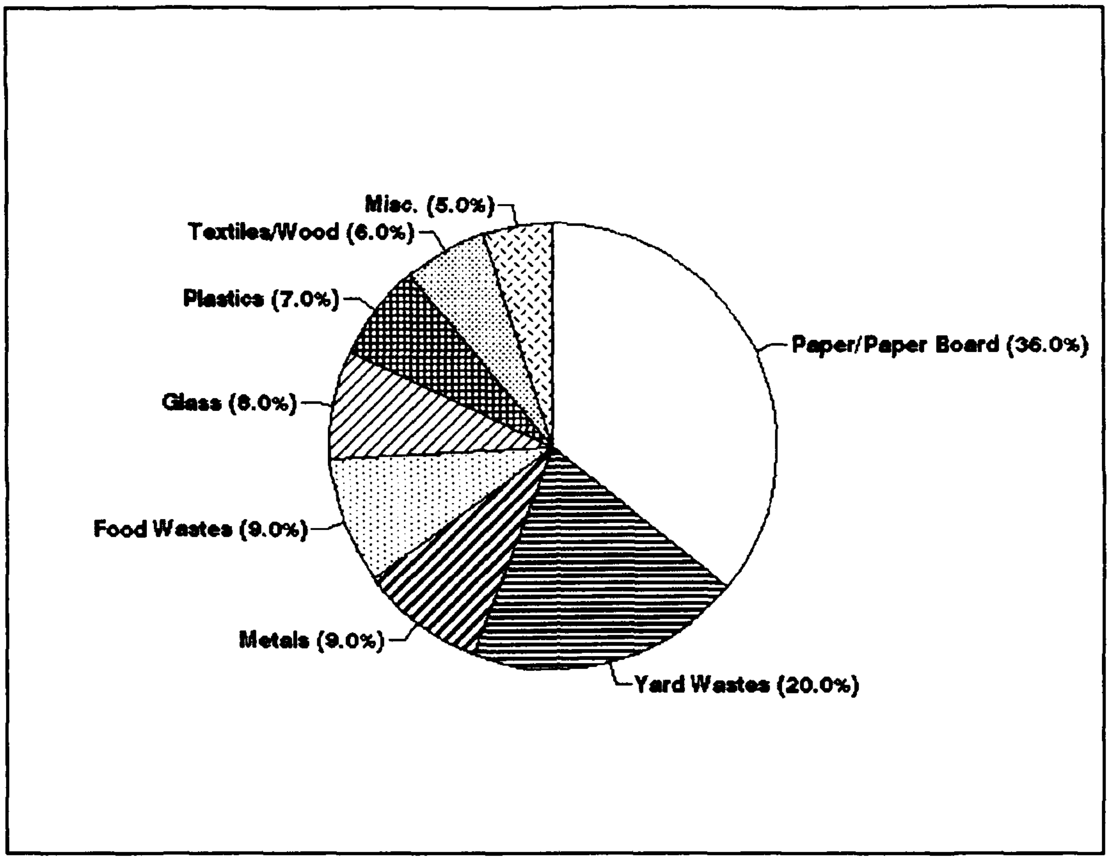

Figure 2. Estimated Percentages of Materials in MSW, by Weight (U.S. Congress, Office of Technology Assessment, 1989:5)

Paper Recycling. The question arises that if paper is a candidate for recycling why does MSW consist of 36% paper? The answer lies in the lack of a profitable market for recycled paper products. The American Paper Institute stated that in the production of 72.9 million tons of paper in the United States in 1986, the paper industry used only 17.8 million tons of recycled paper (American Paper Institute, undated:11). The Institute breaks these numbers down further to show that in the production of 5.6 million tons of newsprint, only 1.4 million tons of recycled paper were used.

There are two main factors that hinder the current use of waste paper in new paper production, economics and quality. Many newspaper publishers and other types of paper companies have investments in virgin paper mills, forcing them to buy products produced at these mills (McDermott, 1989:13). Recycled paper mills are also smaller than virgin paper mills, and therefore, face disadvantageous economies of scale (McEntee, 1989:93). In addition to economic factors, the quality of recycled paper is often inferior to paper made from virgin materials (McDermott, 1989:13). This poor current state of paper recycling has created a large amount of raw materials with few consumers identified and no market infrastructure established (Kraft, 1992:20).

The above problems force much of the waste paper to be disposed of in landfills. However, a possible beneficial alternative to landfilling waste paper is the recycling of waste paper into energy. Reid Detchon, the Department of Energy Principal Deputy Secretary for Conservation and Renewable Energy stated:

> The combustion of waste to produce energy is a form of recycling - the recovery of energy to produce more energy to produce more products. The choice between recycling and combustion of waste newsprint is not a simple and straightforward one. (DOE's Energy Productivity Strategy, 1990:1)

In my opinion, this recycling of waste paper into energy should not face the same public opposition as incineration of wastes as it represents an alternative fuel to coal or natural gas.

Clean Air Act Compliance. The Clean Air Act Amendments of 1990 placed strict requirements on the quantity of sulfur dioxide (SO_2) emissions from utility plants in an attempt to reduce acid rain. The acid rain provisions of this act require the removal of 10 million tons of SO_2, approximately half of the current emissions, by the year 2000 (Commerce Clearing House, Inc., 1990:41).

Over 80% of the current manmade sulfur oxide emissions are produced by the burning of fossil fuels in stationary plants (Masters, 1991:294). The majority of these oxides is SO_2, but a small quantity of sulfur trioxide (SO_3) is also produced. These SO_2 emissions are due to the high quantity of sulfur in coal, approximately 0.5-6 percent (Masters, 1991:295).

The acid rain provisions concentrate mainly on the emissions of large scale utility plants, but other provisions within the act include regulations aimed at smaller sources such as coal-fired boilers on Air Force installations (Arbuckle, 1991:587). These coal-fired boilers produce steam which is used for the heating and production of hot water in buildings. The Air Force is currently investigating modifications that will be required on these boilers to comply with these new emission requirements. Some possible solutions are conversion to natural gas fuel or additional air pollution controls. However, both of these options can be very costly, and a

less expensive alternative may exist in the use of waste paper derived fuel.

Research Objective

The Air Force currently does not burn waste paper in its coal-fired boilers. The Air Force recycles certain high grades of paper for which a profitable market exists and disposes of the remaining waste paper in the MSW stream (Norman, 1992). The purpose of this research is to determine if the waste paper currently being disposed of on Air Force installations can be processed into a technically acceptable, economically feasible fuel for coal-fired boilers.

Investigative Questions

To accomplish the research objective stated above requires addressing the following issues concerning both the technical acceptability and economic feasibility of waste paper derived fuel.

Technical Acceptability. 1. What specific characteristics must a substance possess to be suitable for use as fuel in coal-fired boilers?

2. What are the combustion characteristics of waste paper derived fuel, including thermal output and by-products?

3. What are the specific requirements of the Clean Air Act and other applicable laws regarding alternative fuels in coal-fired boilers?

Economic Feasibility. 1. What fuel cost savings could be realized if waste paper derived fuel is used to supplement coal fuel?

2. What are the costs associated with processing waste paper derived fuel?

3. What costs are associated with modifications to coal-fired boilers and their operation which will enable the use of waste paper derived fuel?

4. What cost savings will be realized from the decrease in landfill and collection fees as waste paper is used as fuel?

5. What is the availability of acceptable waste paper that can be developed into fuel?

Scope of Research

This study examines the acceptability and economic feasibility of using waste paper for fuel in coal-fired boilers. The study does not attempt to justify that using waste paper as fuel is more environmentally sound than recycling paper into new paper products. Instead the study concentrates on determining the technical acceptability and economic feasibility of waste paper derived fuel.

The use of waste paper as fuel may only be a temporary measure pending the development of adequate markets and new technologies that will encourage higher percentages of paper recycling. The possibility of a temporary solution prompts this research to examine methods of burning waste paper in coal-fired boilers that do not require major modifications to the boilers. The study examines the operation of coal-fired boilers to determine the combustion process and required fuel characteristics. However, this study is being conducted from an environmental viewpoint and the details of specific mechanical modifications will only be briefly discussed.

Overview of Research

This chapter addresses the current problem of MSW disposal for both the Air Force and the United States. It looks at the current problems facing the paper recycling industry, and the problems the Air Force will face in complying with the Clean Air Act and pollution prevention directives. The development of waste paper derived fuel for use in coal-fired boilers is suggested as a possible solution to MSW, paper recycling, and Clean Air Act compliance problems.

Chapter two is a review of the literature applicable to waste paper derived fuel. This chapter includes information concerning waste paper and its use as fuel; coal-fired boilers; and relevant USAF, federal, and state environmental regulations concerning the use of waste paper as fuel in coal-fired boilers.

Chapter three presents the methodology that will be used to determine if waste paper derived fuel is both a technically acceptable and economically feasible solution to current problems. The chapter describes the data that is required to make these decisions and how this data needs to be analyzed.

Chapter four specifically addresses the technical acceptability and economic feasibility of using waste paper as fuel in coal-fired boilers. This chapter combines information from previous chapters with new data to answer the investigative questions. This chapter includes an

economic analysis model that can be used at any Air Force installation to determine the economic feasibility of implementing waste paper derived fuel at that installation.

Chapter five summarizes the research effort. This chapter states the conclusions drawn from the study, their practical implications, and presents recommendations for follow-on studies.

II. Literature Review

Overview

This chapter contains information obtained through a thorough literature review of journals, books, and government documents concerned with waste paper and its use as fuel; coal-fired boilers; and relevant USAF, federal, and state environmental regulations concerned with the use of waste paper as fuel in coal-fired boilers. Information was also obtained through interviews with personnel from the Ohio Regional Air Pollution Control Agency, the Wright-Patterson AFB Environmental Branch, the Wright-Patterson AFB Civil Engineering Squadron, and the Institute of Paper Science and Technology.

The chapter is divided into three sections. The first section addresses waste paper with information on the problems associated with the increasing volumes of waste paper and inadequate markets existing for recycled waste paper products. The chemical and physical characteristics of paper in general are discussed, and the section concludes with information concerning the combustion of waste paper. The second section addresses coal-fired boilers, and specifically concentrates on areas relevant to the use of alternative fuels. The final section addresses applicable laws and USAF regulations associated with coal-fired boilers and the use of alternative fuels in these boilers.

Waste Paper

This section contains information regarding the current state of the waste paper recycling market, the composition of paper in general, and the combustion characteristics associated with waste paper.

Paper Recycling. The United States is becoming more environmentally conscious, and as a result, the American public is demanding that waste paper be recycled. However, as was discussed in Chapter I the same people demanding that paper be recycled are not buying recycled products due to their high cost or inadequate quality.

The American Paper Institute stated that in the production of 72.9 million tons of paper in the United States in 1986, the paper industry used only 17.8 million tons of recycled paper (American Paper Institute, no date:11). As of 1990, the current estimate was that the United States recycles about 27 percent of its paper (Rooks, 1990:79).

With the previously mentioned problems of limited landfill space and the public's increased environmental awareness, one would suspect that the United States would be recycling much more than 27 percent of its waste paper. There are two main reasons for this low recycling rate, poor economics and lack of technology to produce quality products (McDermott, 1989:13).

The poor economics of paper recycling can be shown by a comparison between paper recycling and aluminum recycling.

The price paid by aluminum recycling companies for aluminum cans ranges from $600-$1000 per ton (Ohio Department of Natural Resources, 1991:22). The price paid by paper recycling mills for a ton of old newspapers ranges from $31 per ton in Los Angeles to receiving $2.50 per ton to accept old newspapers in New York City (Apotheker, 1992:28). The reason for this vast difference in prices is that it is much more economical to recycle aluminum than to produce it from raw materials; whereas, it is less expensive to produce paper from raw materials than to recycle it. This cost difference is due mainly to the ease in which trees, the raw material for paper, can be harvested versus the difficulty in mining bauxite, the raw material for aluminum. Recycling aluminum also takes 95 percent less energy than producing aluminum from bauxite (Chiras, 1990:446). These factors have created a profitable market which recycles 64 percent of aluminum cans (Charles, 1992:12).

There are several other economic reasons that hinder the recycling of paper. These reasons include the costs associated with deinking waste paper and the small scale plants involved in paper recycling (Brinckman, 1993:4). Also, many of the large publishing companies responsible for much of the paper use have financial interests in at least one virgin-paper mill. The <u>New York Times</u> has investments in three Canadian virgin-paper mills and as a result uses little recycled newsprint (McDermott, 1989:13). Another economic disincentive to paper recycling is the Federal

resource-management practices that result in the underpricing of virgin materials in an attempt to stimulate economic growth (Shea, 1988:15). This is exemplified by the U.S. Forest Service selling lumber over the past ten years at $2 billion below their costs of planting and tending trees and building access roads (Shea, 1988:15).

The problem of recycling paper is not only one of economics but also one of inadequate quality. Dennis Washburn, a buyer for the Gannett newspaper chain, states that recycled newsprint is less bright and absorbs more ink which creates fuzzier, muted images (McDermott, 1989:13). Also because paper fibers are broken and shortened in the recycling process, recycled paper products tend to be weaker than virgin paper (White, 1990:99).

These economic and quality problems have hindered the development of a profitable market that would encourage high paper recycling rates. The government's solution to the lack of a profitable market has been an attempt to legislate one into existence. As of 1992, 38 states had enacted laws strongly encouraging recycling (Kraft, 1992:20). This legislation has created an enormous supply of raw materials by encouraging recycling, but the legislation has failed to create the demand for recycled products or the infrastructure to produce them.

Many of the companies currently involved in the collection of recyclable products are losing money and creating stockpiles of the recyclable goods as they wait for

a demand to develop (Charles, 1992:13). This current lack of a profitable market encourages federal, state, and local governments to subsidize paper recyclers for environmental reasons. However, an economic analysis of waste paper recycling suggested that government price subsidies are not the solution and that research and development into new waste paper uses would be more beneficial (Edgren and Moreland, 1990:318).

One area for research and development was recommended by Department of Energy Principal Deputy Assistant Secretary for Conservation and Renewable Energy, Reid Detchon, who suggested a possible alternative exists in the recycling of waste paper into energy by using it as a fuel (DOE's Energy Productivity, 1990:1). Detchon states that waste paper derived fuel has both economic and environmental benefits, and that using newsprint as a fuel would provide 8000 Btu per pound; whereas, the recycling of newsprint saves only 2000 Btu per pound. To make recycling more economically feasible than using paper as fuel would require waste paper be recycled at least four times.

Paper Composition. To look further into the feasibility of burning waste paper requires determining the composition of paper in general. There are many different types of paper produced for a large variety of products. Paper products range from newsprint, magazine and book stock, corrugated boxes, office paper, and many other varieties. The main ingredients in all of these paper

products are basically the same: pulp, fillers, and coatings. Some papers may also contain dyes to alter their color or be printed on using various types of inks. Many of the ingredients that impart desired properties to specific types of paper and printing inks are proprietary in nature (Krause, 1993).

Pulp. According to the Technical Association for the Pulp and Paper Industry (TAPPI), the main ingredient in paper is the fibrous raw material, pulp (Smook, 1982:36). Pulp is produced by either mechanically, thermally, or chemically rupturing the bonds in the wood structure and producing a fibrous mass.

The main ingredients in wood and therefore in pulp are cellulose, hemicellulose, lignin, and extractives. Cellulose, $(C_6H_{10}O_5)^n$, is the substance in wood that provides the properties required for paper making. The degree of polymerization, n, varies from 600-1500 in commercial wood pulps, and is dependent on the type of wood used. Cellulose makes up 45 percent of wood (Smook, 1982:6). Hemicellulose makes up 25 percent of wood and consists of a polymer of five different sugars formed from carbon, hydrogen, and oxygen (Smook, 1982:5). Lignin makes up 25 percent of wood and is the substance that holds the cellulose and hemicellulose together (Smook, 1982:6). Lignin possesses a very complex chemical structure of carbon, hydrogen, and oxygen which can be described as phenyl propane units linked together in three dimensions. The final group of compounds

present in wood, extractives, make up 1 to 5 percent of the wood (Smook, 1982:6). Extractives are organic substances such as resin acids, fatty acids, turpenoid compounds, and alcohols.

Paper Fillers. Fillers are used in almost all paper grades to impart specific desired properties to the final product (Casey, 1981:1515). Fillers are very important in enhancing the printability and optical properties of paper.

The percentages of filler added to the pulp can range from 10-30 percent depending on the type of filler and the properties desired (Casey, 1981:1519). The primary fillers used are clay ($Al_2O_3*2SiO_2*2H_2O$) and calcium carbonate ($CaCO_3$). Other commonly used fillers include talc ($H_2Mg_3*4SiO_3$), titanium dioxide (TiO_2), zinc sulfide (ZnS), calcium sulfate ($CaSO_4$), diatomaceous silica (unknown), and blanc fixe ($BaSO_4$) (Casey, 1981:1516-1518; Howard and Neal, 1992).

Paper Coatings. Coatings are applied to many paper grades to achieve a uniform surface for printing, to enhance opacity, or to improve the quality of paper made from low grade fibers (Loomer, 1970:517). Common pigments used for coating include china clay ($Al_2O_3*2SiO_2*2H_2O$), calcium carbonate ($CaCO_3$), titanium dioxide (TiO_2), satin white ($Al_2O_{18}S_3*6Ca*nH_2O$), and aluminum trihydrate (AlH_3O_3).

To facilitate dispersion of the pigments on the paper surface substances labeled dispersants are added to the

pigment Common dispersants are polyphosphates, modified sodium hexametaphosphate ($6NaP_6O_{18}$), casein (a milk protein), soy protein, and oxidized starch (Loomer, 1970:518).

To enhance the binding of the paper coatings to the paper, substances labeled as binders are also added to the pigments. Common binders include modified starch (predominantly corn), casein, soy bean protein, polyvinyl alcohols, synthetic latices (styrene-Butadiene, acrylics, vinyl acetates), and other synthetics (methyl cellulose, carboxymethyl cellulose, poly-vinyl pyrrolidone) (Loomer, 1970:518).

Paper Dyes. Most colored papers are dyed with water soluble dyes that can be categorized as acid, basic, or direct (Schwalbe, 1970:82). The acid dyes consist of sodium and potassium salts; the basic dyes consist of chlorides, hydrochlorides, sulphates, and oxalates; and the direct dyes are also sodium salts (Schwalbe, 1970:82-84).

Printing Inks. As was mentioned earlier many of the components that give printing inks their color and specific traits are proprietary in nature. However, the main components are usually similar. The vehicle, or bulk, of the ink consists of heat-treated linseed oil (Cogoli, 1973:292). The pigment, or color, is usually manufactured from coal tar which is a by-product of the manufacture of coke from coal (Cogoli, 1973:292). A review of Material Safety Data Sheets (MSDS) for various types of inks also

revealed the use of petroleum oil vehicles and carbon black pigments (Repeat-O-Type, 1989).

Combustion Characteristics. To understand how the above paper components will react when used as fuel requires a basic understanding of the combustion process and essential fuel characteristics. The combustion of solid fuel can be described by the following reaction sequences:

> 1) fuel particle drying, and then particle heating to pyrolysis reaction temperature;
>
> 2) solid particle pyrolysis to produce combustible and non-combustible volatiles and a carbonaceous char; and
>
> 3) char oxidation after pyrolysis ceases, with the combustible volatiles being oxidized in reactions which occur simultaneously with the heterogeneous char oxidation process. (Tillman, 1991:9)

Pyrolysis is the heating of a substance in the absence of oxygen which produces the following substances: volatiles, char, and tar (Tillman, 1991:15). Volatiles are substances in the gaseous phase. Tar is a heavy hydrocarbon-like substance with a hydrogen/carbon ratio greater than one. Char is a carbon rich solid with small amounts of hydrogen, oxygen, and any other atoms present in the fuel (Tillman, 1991:16).

To specifically represent the above reactions requires information concerning the fuel characteristics and combustion temperature range. The specific fuel characteristics are density, thermal conductivity, heat capacity, elemental composition, calorific or heating value, particle size, proximate analysis, and thermogravimetric

characteristics (Tillman, 1991:4,10). These characteristics for waste paper are discussed later in Chapter IV.

Combustion of an organic substance, such as paper or coal, consists of a process in which the hydrogen (H) and carbon (C) in the fuel combine with the oxygen (O) in the air. Complete combustion results in hydrogen combining with oxygen forming water vapor, and carbon combining with oxygen to form carbon dioxide. Complete combustion is modeled by the following two equations:

$C + O_2 \rightarrow CO_2$ (carbon dioxide)

$2H + O_2 \rightarrow 2H_2O$ (water) (Kohan, 1991:346).

Incomplete combustion results in the formation of carbon monoxide (CO), hydrocarbons, and several other gases (Cheremisinoff, 1980:48).

As stated above, one characteristic that a fuel must have is heating value. This heating value represents the energy released during the combustion of the fuel and is usually expressed in Btu per pound (Kohan, 1991:352). The comparison between heating values of waste paper and coal is important to determining the value of waste paper as a fuel substitute. Table 1 contains the average heating values for various paper products and wood. These values can be compared with bituminous coal, a major fuel in coal-fired boilers, which has an energy content of 12,450 Btu per pound (Kohan, 1991:354)

TABLE 1

ENERGY CONTENT OF VARIOUS MATERIALS

MATERIAL	ENERGY CONTENT (Btu per pound)
NEWSPAPER	8,000
CORRUGATED BOXES (PAPER)	7,000
WOOD	6,700

(Council on Plastics and Packaging in the Environment, 1989:2)

Coal-Fired Boilers

There are many different types of coal-fired boilers currently in operation throughout the world. The majority of boilers currently being operated on USAF installations are of the traveling-grate spreader stoker variety, and therefore, description of this type of boiler is emphasized (Solomon, 1993). This section briefly discusses the design of travelling-grate spreader stoker boilers and then focuses on the three requirements needed to determine the acceptability of burning alternative fuels in these boilers: 1) the specific fuel characteristics required to allow co-combustion with coal, 2) the combustion temperature range, and 3) the types of emissions controls available.

Travelling-Grate Spreader Stoker Boilers. A coal-fired boiler is a device that generates steam or hot water for heating or hot water supply purposes (Shields, 1961:4). A travelling-grate spreader stoker boiler operates by rotating paddles, the spreader stoker, throwing coal onto a travelling-grate. The coal is burned as the grate moves the

fuel to the end of the furnace, at which time only ash remains, which is dumped off the grate into a storage bin . The boiler walls surrounding the furnace contain tubes of circulating water that are heated to provide either steam or hot water depending upon the pressure of the system (Kohan and Spring, 1991:358; Gibson, 1993).

Figure 3 shows a typical travelling-grate spreader stoker boiler. Figure 4 shows a more detailed view of the travelling-grate and spreader stoker sections of the boiler. Figure 5 shows a detailed view of the spreader stoker mechanism, overthrow rotor, that distributes coal onto the grate.

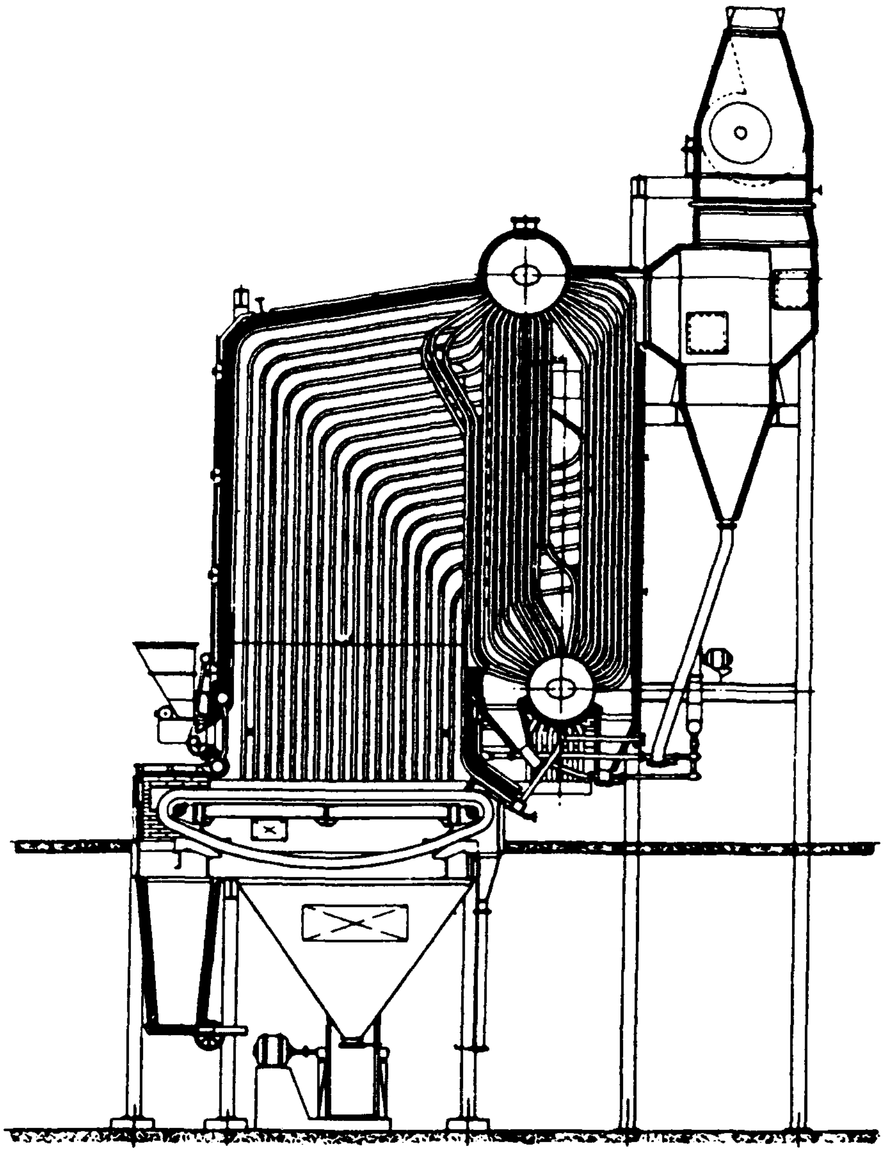

Figure 3. Typical Travelling-Grate Spreader Stoker Boiler (Shields, 1961:37)

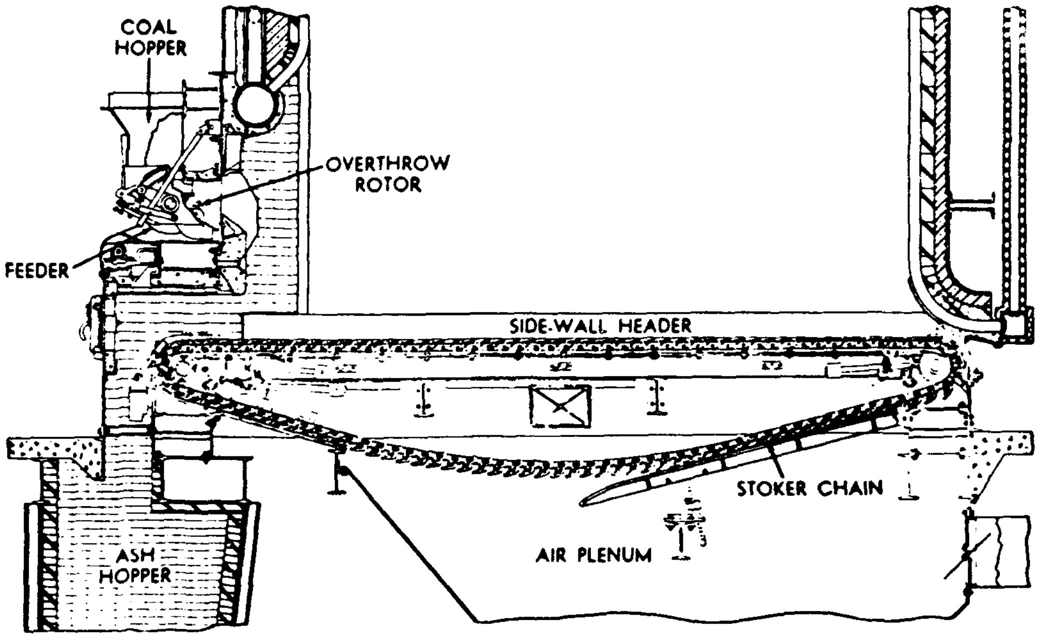

Figure 4. Travelling-Grate Spreader Stoker (Babcock and Wilcox, 1963:16-12)

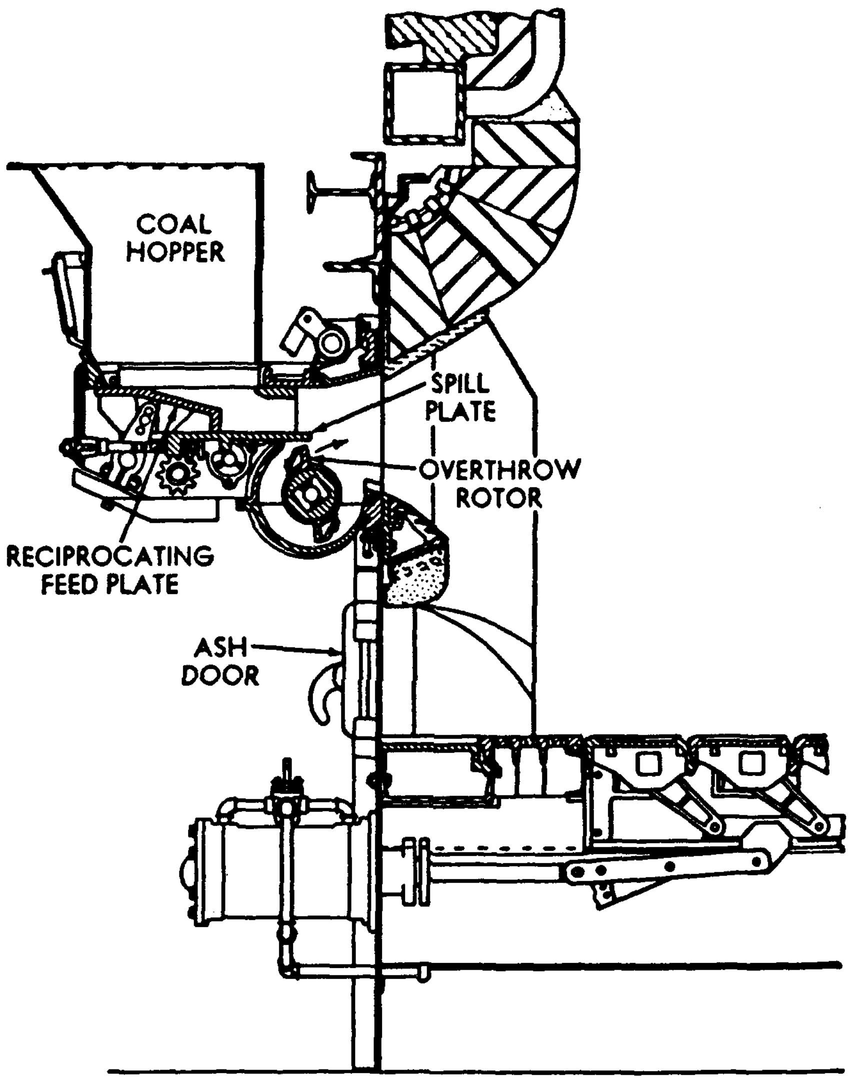

Figure 5. Spreader Stoker Mechanism (Babcock and Wilcox, 1963:16-10)

Coal Handling Systems. (Schmidt, 1989:3-4 to 3-9) Travelling-grate spreader stoker boilers burn coal in its whole form. The boilers must have a system for moving the coal from delivery vehicles into the boiler. Most coal is delivered to the boiler site by either railroad car or truck. After the coal is unloaded, it may be transferred by bucket elevators, belt conveyors, or similar mechanisms into storage silos. Additional coal surplus may be temporarily stored outside or beneath a shelter to protect it from the weather. From the silos or outside storage, the coal is transferred via belt or bucket conveyors into bunkers located above the boilers. These bunkers contain scales to record the amount of coal fed into each boiler.

Figure 6 shows a typical coal handling system for truck delivery. The coal in this system is transferred directly from the truck into a bucket elevator which then transfers the coal into a bunker which feeds the stoker in the boiler. Figure 7 shows a similar system to Figure 6 with the exception of a coal silo added for additional coal storage capacity.

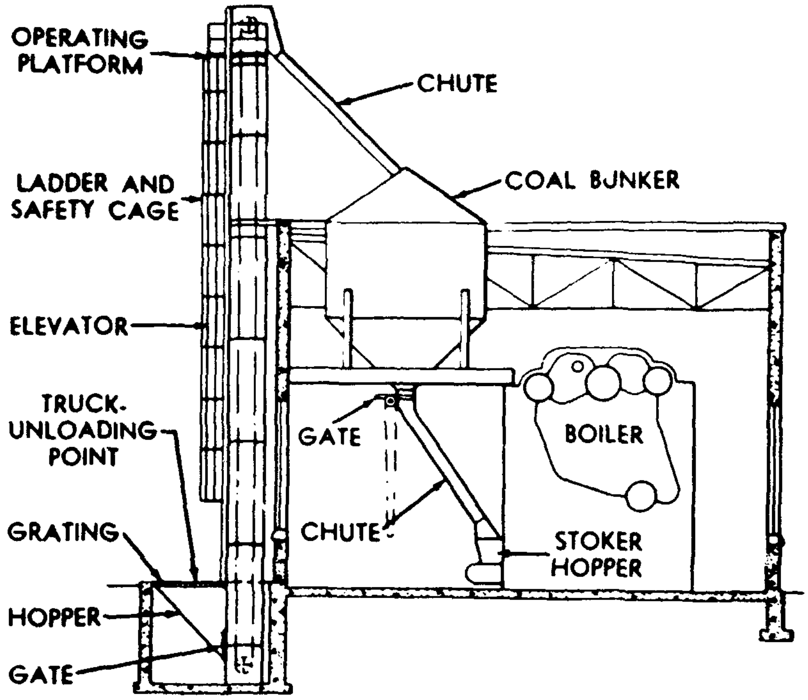

Figure 6. Coal Handling Equipment, Truck Delivery (Babcock and Wilcox, 1963:15-12)

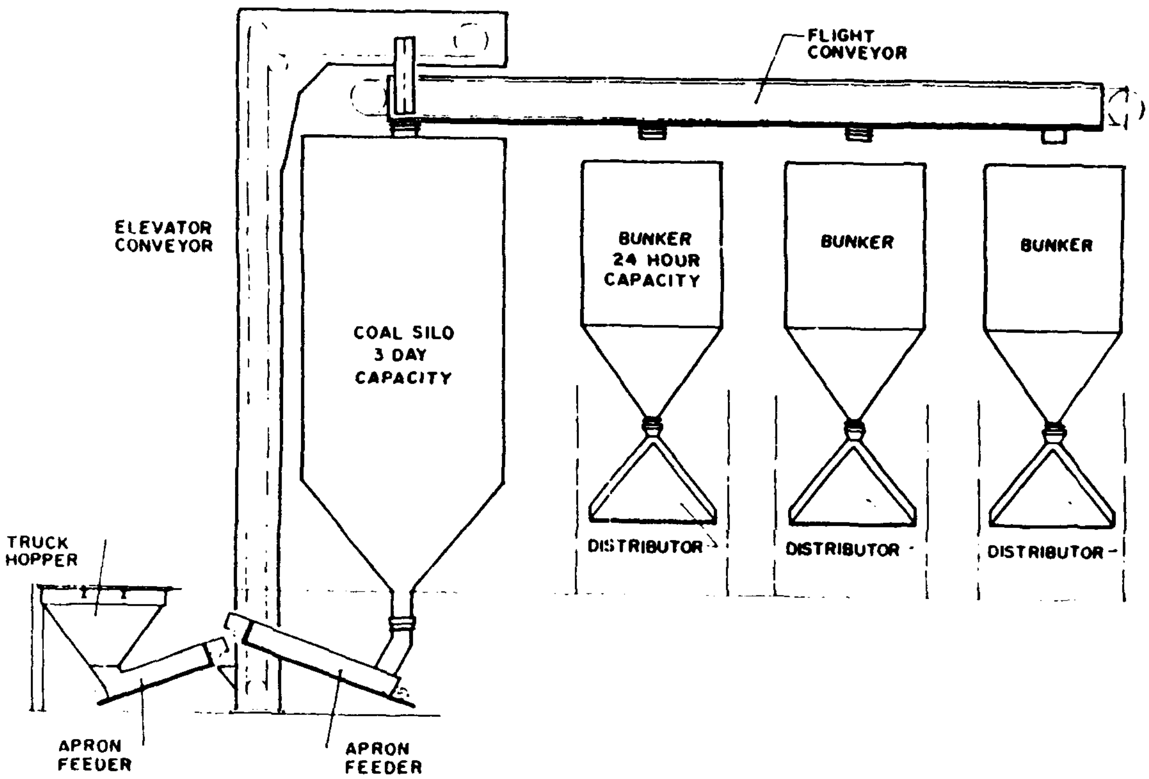

Figure 7. Coal Handling Equipment, Truck Delivery with Additional Silo Storage (Schmidt, 1989:3-12)

Coal delivery systems that incorporate silos are more desirable due to their ability to make the coal handling system more automated. Another item that reduces maintenance of coal handling systems is rubber belt conveyors. Belt conveyors can carry coal up inclines as steep as 18 degrees and take the place of bucket elevators which require constant cleaning due to fine coal particles sticking to the inside of the buckets and reducing their capacity (Schmidt, 1989:1-5,3-7). Figure 8 shows a typical rubber conveyor belt.

Figure 8. Rubber Belt Conveyor for Coal Transport (Gaffert, 1952:446)

Fuel Characteristics. To properly function as an acceptable fuel in the above described travelling-grate spreader stoker boilers there are several requirements that

coal, or other alternative fuels, must satisfy. These requirements include percent moisture, percent volatile matter, percent ash, ash fusion temperature, percent sulfur, heat or Btu content, and size (Woodruff and Lammers, 1977:117-124). The specifications for coal used in Wright-Patterson AFB boilers are shown in Appendix A.

The moisture content of coal is important in preventing handling problems. Too high a moisture content will cause coal to stick to conveyor belts and buckets preventing its flow to the boiler (Woodruff and Lammers, 1977:122).

The percentage of volatile matter in coal determines the amount of volatile gases generated by the coal as it is heated. The higher the percentage of volatile matter the more combustion that will take place in gases above the fuel bed (Woodruff and Lammers, 1977:121). This combustion above the fuel bed versus in the fuel bed requires a larger combustion area to prevent fuel loss and smoke. However, a high percentage of volatile matter also increases combustion efficiency (Tillman, 1991:354). The ideal percentage of volatile matter is one that promotes combustion efficiency, and also permits sufficient combustion in the fuel bed to maintain an acceptable bed temperature.

Both the minimum and maximum percentages of ash, the incombustible inorganic matter in coal, are important. The minimum percentage of ash is important due to the travelling-grate section of the boiler needing to be protected from the direct heat of the combustion by a layer

of ashes. The maximum percentage is important because it represents an inert material that will not produce heat and that must be removed from the boiler and disposed of as waste (Woodruff and Lammers, 1977:124).

The ash fusion temperature, or melting point, is also an important characteristic in ensuring proper boiler operation (Woodruff and Lammers, 1977:119). Ash at its melting point has a tendency to stick together and form an undesirable layer on heat-exchange surfaces in the boiler (Raask, 1985:158).

The percentage of sulfur in coal is important in determining the percentage of sulfur dioxide emissions, a criteria air pollutant, from the combustion process. Besides polluting the air the sulfur dioxide combines with water vapor in the boiler forming sulfurous acid which corrodes many of the steel components in the boiler (Kohan, 1991:399). Table 2 lists the percentage of sulfur (S) found in various types of coal mined throughout the United States.

The heat content of the coal is obviously important as it is a direct measure of the coal's effectiveness as a fuel. Both the moisture and ash content of coal reduce its heat content on a per pound basis. Table 3 lists various coals mined throughout the United States and their energy content along with other characteristics important to their use as fuel.

Table 2

TYPICAL SULFUR PERCENTAGE IN VARIOUS TYPES OF COAL

TYPE	SOURCE	SULFUR (%)
Anthracite	Pennsylvania	0.6
Bituminous	Pennsylvania	2.17
Bituminous	Ohio	2.44
Subbituminous	Colorado	0.36
Lignite	North Dakota	1.42

(Kohan, 1991:354)

Table 3

TYPICAL COAL PROPERTIES

TYPE	SOURCE	HEATING VALUE (Btu/lb)	PROXIMATE ANALYSIS MOISTURE (%)	VOLATILES (%)	FIXED C (%)	ASH (%)
Anthracite	Pennsylvania	13,000	2	6.3	79.7	12
Bituminous	Pennsylvania	13,600	3	23.1	63.9	10
Bituminous	Ohio	12,450	6	34.8	49.2	10
Subbituminous	Colorado	9,200	24	30.2	40.8	5
Lignite	North Dakota	6,330	40	27.6	23.4	9

(Kohan, 1991:354)

The final characteristic of coal that must be specified is the size. The size is important in ensuring proper handling and combustion of the coal. Coal size is usually specified by designating the percentage of coal passing through various screen diameters (Woodruff and Lammers, 1977:123). For the spreader stoker boilers at Wright-

Patterson AFB, the size was specified as 5 percent maximum retained by 1.25 inch screen and 15 percent maximum passing through a 0.25 inch screen (see Appendix A).

Combustion Temperature Range. The temperature range for travelling-grate spreader stoker boilers is dependent upon the amount of fuel and air present in the boiler. The typical temperature of the boiler furnace ranges from 2200-2400 degrees Fahrenheit (Shields, 1961:172). The maximum temperature must not exceed the ash fusion temperature of the coal, which varies depending upon the type of coal (Solomon, 1993). The coal purchased at Wright-Patterson AFB was specified to have an ash fusion temperature of at least 2300 degrees Fahrenheit (see Appendix A).

Emission Controls. Amendments to the Clean Air Act passed in 1990 greatly overhauled the Clean Air Act of 1970. The amendments included new standards for industrial boilers concerning toxic air pollutants and acid rain (Arbuckle and others, 1991:524). To comply with these standards coal-fired boilers employ several types of emission controls. The emission controls can be broken down into three categories: nitrogen oxides (NO_x) controls, sulfur dioxide (SO_2) controls, and particulate controls (Masters, 1991:349-353). The understanding of these emission controls is important in determining the controls' effectiveness on emissions from alternative fuels such as waste paper derived fuel.

NO_x can be formed when nitrogen and oxygen in the combustion air are heated to a sufficient temperature, approximately 1273 degrees Centigrade, to oxidize the nitrogen. NO_x can also be formed from the oxidation of nitrogen compounds in the fuel (Masters, 1991:284).

One method implemented in travelling-grate spreader stoker boilers to decrease the amount of NO_x produced is to limit the amount of air made available for combustion to the minimum required for complete combustion. This method, termed low excess air, can reduce NO_x emissions from 15 to 50 percent (Masters, 1991:349).

The sulfur in coal is mostly released as SO_2 during the combustion process. SO_2 may then be converted to sulfur trioxide (SO_3) which reacts with water vapor to form sulfuric acid (H_2SO_4) (Masters, 1991:295). This sulfuric acid is what many feel is a major contributor to the acid rain phenomenon.

One method to remove the SO_2 from coal emissions is known as wet flue-gas desulfurization. This process involves the spraying of pulverized limestone ($CaCO_3$) mixed with water into the flue gas. The SO_2 is absorbed by the spray, creating calcium sulfite (Masters, 1991:349). The process is represented in equation form as

$$CaCO_3 + SO_2 + 2H_2O \rightarrow CaSO_3\text{-}2H_2O + CO_2$$

The process can remove up to 90 percent of the SO_2, but is very expensive. The initial capital costs of this system

represent 10-20 percent of the total capital cost of the power plant (Masters, 1991:350).

The final type of emission controls on boilers are designed to regulate particulate emissions. For larger particles, the most common control device is a centrifugal collector, or cyclone (Masters, 1991: 351). The cyclone is designed so the emission gases spin in a cylindrical shell forcing the larger particulates to collide with the outer walls where gravity causes the particulates to fall into a collection hopper. Figure 9 shows a typical cyclone. Cyclones can remove up to 90 percent of particulates larger than 5 microns ($5x10^{-6}$ m).

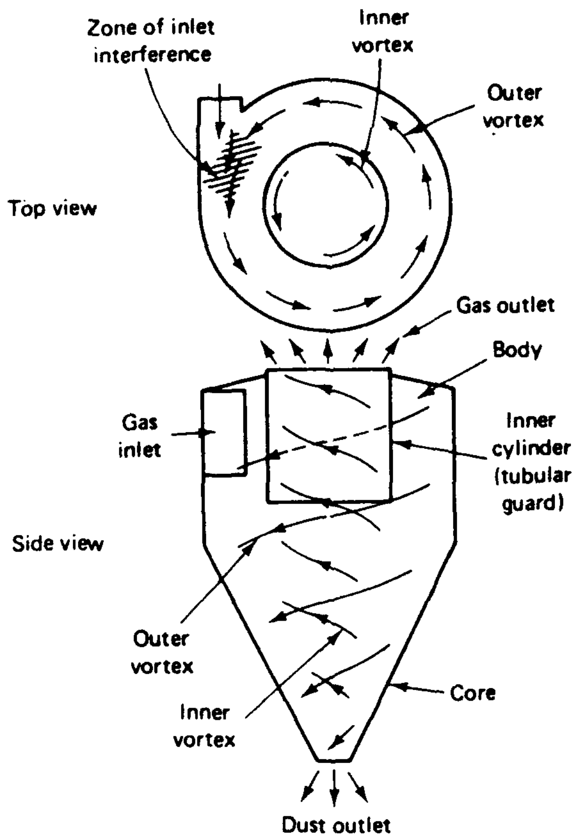

Figure 9. Typical Cyclone Emission Control (Masters, 1991:351)

To control smaller particulates which are more dangerous to human health, baghouses or electrostatic precipitators are used. Electrostatic precipitators use a strong electric field in the path of the exiting emissions to cause particulates to stick to grounded metal plates. The particulates are then removed form the plates by gravity or vibration. Electrostatic precipitators can remove up to 98 percent of the particulates, including submicrometer particulates (Masters, 1991:351). Figure 10 shows a cutaway view of a typical electrostatic precipitator.

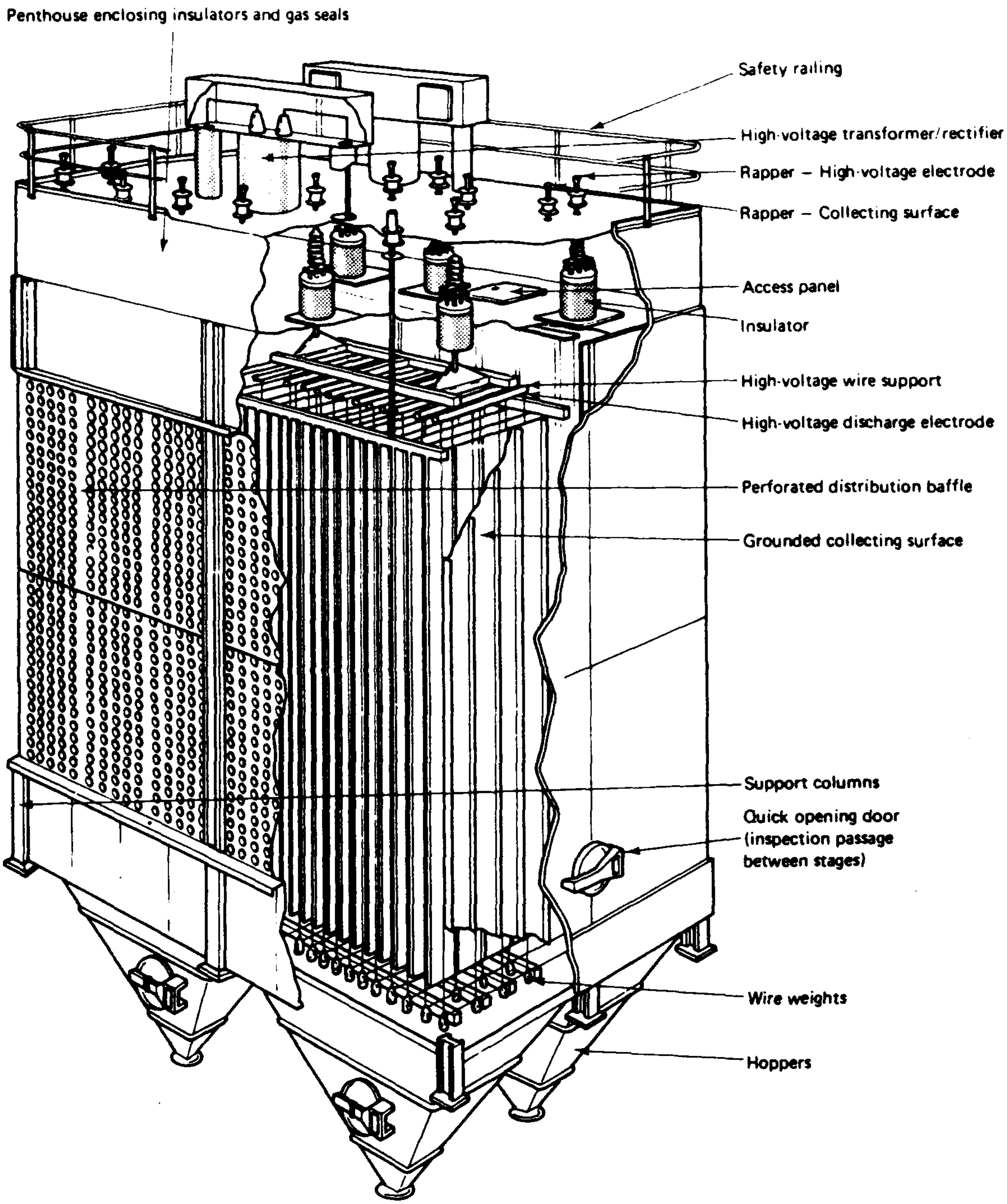

Figure 10. Electrostatic Precipitator Emission Control (Masters, 1991:353)

Another method for removing small particulates is by fabric filtration in devices termed baghouses. These baghouses contain filter bags suspended upside-down in a large chamber though which the emission gases are directed. The filter bags, which are capable of removing nearly 100 percent of particulates greater than 1 micron, require periodic cleaning to remove the particulates (Masters, 1991:354). Figure 11 shows a typical fabric filter baghouse.

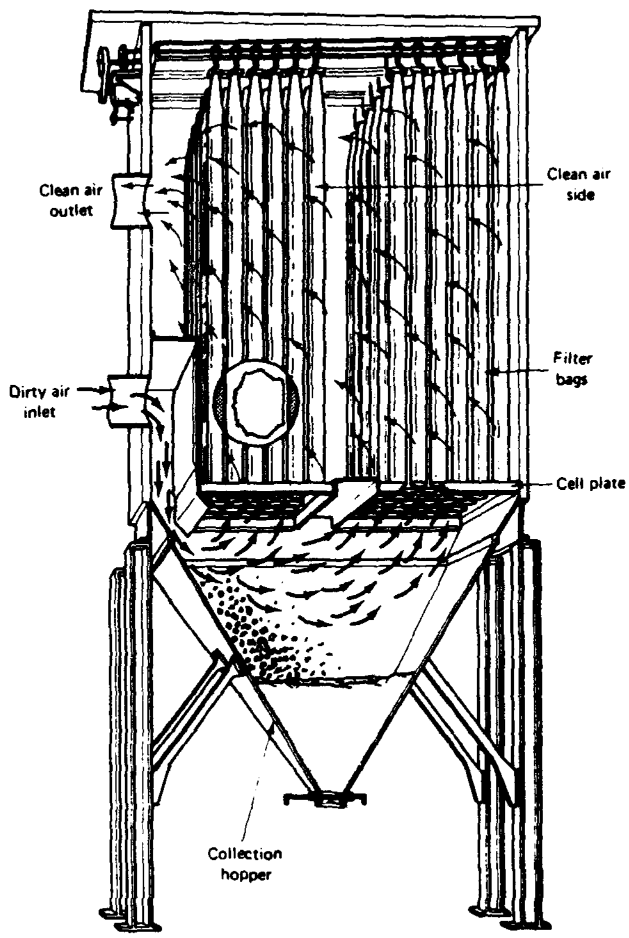

Figure 11. Fabric Filter Baghouse Emission Control (Masters, 1991:355)

Applicable Laws and Regulations

The major relevant Federal laws concerning burning waste paper derived fuel in coal-fired boilers are the Clean Air Act (CAA) which deals with air emissions and the Resource Conservation and Recovery Act (RCRA) which deals with solid waste disposal (Rogoff, 1992:E-62). The CAA has delegated certain authorities to states to carry out and enforce the provisions of the act. The USAF has issued Air Force Policy Directive 19-4, Pollution Prevention, to specifically provide guidance and directives to ensure USAF compliance with all Federal pollution prevention objectives, including solid waste reduction (Department of the Air Force, 1992:1). These laws and policies are discussed below in order to determine if waste paper derived fuel is capable of complying with them.

Clean Air Act. The Clean Air Act Amendments of 1990 (CAA of 1990) created major revisions to the Clean Air Act originally passed in 1970. Three goals of the CAA of 1990 are to control acid rain, regulate toxic air emissions, and control emissions of ozone depleting chemicals (Arbuckle and others, 1991:524). To meet these goals the CAA of 1990 set up an elaborate permit program and strengthened enforcement provisions. The goals of controlling acid rain, regulating toxic air emissions, and the permit program are all relevant to coal-fired boiler operation and waste paper derived fuel.

The CAA of 1990 encourage states to develop their own implementation plans to carry out the provisions of the

federal act (Wagner, 1993). These state implementation plans must at a minimum meet all federal requirements, and if states so choose, may implement more stringent requirements. This section mainly focuses on federal regulations, but a brief discussion of regulations implemented by the state of Ohio is included as an example of specific state policies.

CAA of 1990 Title IV: Acid Rain. As was mentioned in Chapter I, the CAA of 1990 attempts to reduce acid rain by requiring the removal of 10 million tons of SO_2 emissions from electric utility plants based on 1980 levels by the year 2000 (EPA, Acid Rain Program, 1992:1). Phase I of Title IV begins in 1995 and affects 110 electric utility plants in 21 eastern and midwestern states. Phase II begins in the year 2000 and will affect 2,200 smaller utility plants (EPA, Acid rain Program, 1992:1-3). In addition to SO_2 emission controls, Title IV also requires a 2 million ton reduction in NO_x emissions from 1980 levels by the year 2000 (EPA, Acid Rain Program, 1992:1).

The Acid Rain Program is mainly directed at large electric utility plants instead of smaller industrial boilers such as those on Air Force installations. However, if the program is not successful in reducing acid rain the possibility exists for coal fired industrial boilers to also be required to obtain allowances.

CAA of 1990 New Source Performance Standards. Section 111 of the CAA of 1990 authorizes the EPA Administrator to set emission standards for any new or modified source which contributes significantly to air pollution which may endanger public health or welfare (Arbuckle and others, 1991:537). These sources are listed in the Code of Federal Regulations, 40 Part 60, Standards of Performance for New Stationary Sources. This regulation lists industrial-commercial-institutional steam generating units as priority 11 out of the 59 major source categories listed (Code of Federal Regulations, 1992:233). Therefore, any new boilers built on Air Force installations will have to comply with these standards, and boilers modified to burn waste paper may have to comply depending upon their emissions.

The EPA has set emission standards for sources when feasible, and has set design, equipment, or operational standards where numerical emission standards are infeasible (Arbuckle and others, 1991:537). The standards list specific maximum levels for emissions of particulate matter, sulfur dioxide, and nitrogen oxides (Code of Federal Regulations, 1992:248-249).

CAA of 1990 Hazardous Air Pollutants. Section 112 of the CAA of 1990 regulates emissions of 189 toxic air pollutants through technology and, if necessary, health based standards (Arbuckle and others, 1991:561). The 189 regulated substances are listed in Appendix B.

The sources regulated by Section 112 are labeled major and area sources. A major source is a stationary source which has the potential to emit 10 tons of any hazardous air pollutant per year or 25 tons per year of any combination of hazardous air pollutants. An area source is defined as all sources of hazardous air pollutants besides vehicles and major sources. The EPA administrator has been tasked to categorize the area sources that emit 90 percent of the 30 most hazardous air pollutants by 1995 (Commerce Clearing House, 1990:132).

<u>CAA of 1990 Solid Waste Combustion</u>. Section 129 of the CAA of 1990 specifically addresses emissions from solid waste combustion. This section deals with solid waste incinerators and utility or industrial plants whose fuel streams consist of over 30 percent municipal waste (Commerce Clearing House, 1990:207).

Congress has specified the pollutants to be addressed by this section to be: total and fine particulate matter, sulfur dioxide, hydrogen chloride, nitrogen oxides, carbon monoxide, lead, cadmium, mercury, dioxins, and dibenzofurans (Arbuckle and others, 1991:539). The emission standards for these pollutants should take into consideration costs, health and environmental impacts, and energy requirements.

<u>CAA of 1990 Title V: Permits</u>. Title V of the CAAA established an operating permit program similar to the National Pollutant Discharge Elimination System (NPDES) created by the Clean Water Act to deal with waste water

discharges (Arbuckle and others, 1991:586). The permitting program is the most important reform to the CAA as it clarifies and provides for enforcement of a source's pollution control requirements (U.S. Environmental Protection Agency, 1990:6).

A source will require a permit if it emits more than 100 tons per year of any air pollutant; or if it emits less than 100 tons per year, but emits more than 10 tons per year of any hazardous air pollutant or a combination of 25 tons of hazardous air pollutants (Arbuckle and others, 1991:587). Sources located in air quality nonattainment areas may be required to obtain a permit based on the severity of the nonattainment problem. The administrator of the EPA also has the authority to designate additional sources that will require a permit.

As stated earlier, the CAA has delegated certain authorities to states to carry out and enforce the provisions of the act. One area where this authority has been delegated is in the issuing of permits. Ohio's permit requirements are discussed below as a representative sample, and to aid in the Chapter IV case study of a boiler at Wright-Patterson AFB, Ohio.

Ohio Air Permits. The Ohio Environmental Protection Agency has authority for CAA compliance in the state of Ohio (Wilson, 1993). This authority has been delegated to the Regional Air Pollution Control Agency (RAPCA) for a six county area which includes Wright-

Patterson AFB (Regional Air Pollution Control Agency, 1993:1).

RAPCA is responsible for issuing the permits required by Wright-Patterson AFB to operate its six coal-fired boilers. These permits, see Appendix C for an example, contain specific requirements regarding boiler air emissions including: 0.10 pounds of particulate emissions per million Btu actual heat input and 2.0 pounds of sulfur dioxide emissions per million Btu actual heat input (Ohio Environmental Protection Agency, 1990).

In addition to the air emissions requirements, the permits require strict regulation of the coal that is used to power the boilers. These coal regulations include taking a daily representative sample of the coal being burned and combining these daily samples every month to obtain a composite sample of coal to be tested for ash content, sulfur content, and heat content (Ohio Environmental Protection Agency, 1990). Similar sampling requirements would need to be met for any alternative fuels, including waste paper derived fuel, that will be burned in the boilers (Wilson, 1993).

Resource Conservation and Recovery Act. The Resource Conservation and Recovery Act of 1976 (RCRA) is designed to provide cradle-to-grave control of hazardous waste (Arbuckle, 1991:406). Currently RCRA does not consider ash produced from municipal solid waste incineration as hazardous waste, and therefore this ash is not regulated.

However, the possibility of RCRA being amended to include regulation of this ash is high (Rogoff, 1992:E62).

There are two types of ash produced when waste is used as a fuel, bottom ash and fly ash. Bottom ash is the solid material that remains when a fuel is not entirely burned. Fly ash consists of the fine particles collected from the air emissions control equipment on the boiler. These ashes are currently being collected and disposed of in landfills as ordinary solid waste, but as stated above, these ashes may require special handling as hazardous waste in the future.

Air Force Policy Directive 19-4, Pollution Prevention. The purpose of Air Force Policy Directive 19-4, Pollution Prevention, is to provide environmental guidance to ensure that the USAF meets all Federal pollution prevention objectives by eliminating or reducing the use of hazardous substances and the release of wastes to the environment (Department of the Air Force,1992:1-3). This directive specifically addresses the problem of municipal solid waste by directing the Air Force to reduce its municipal solid waste by recycling and source reduction.

An action memorandum issued in 1993 by the USAF Chief of Staff stated specifically that municipal solid waste disposal would be reduced by the end of 1997 to 50 percent of the 1992 baseline (Department of the Air Force, Air Force Pollution Prevention Program, 1993:5).

Summary

This chapter reviewed information that is necessary in determining the feasibility of using waste paper derived fuel. This information included a discussion of waste paper characteristics; coal-fired boilers; and USAF, federal, and state environmental regulations relevant to the use of waste paper as fuel in coal-fired boilers. This information was obtained from current literature and interviews with personnel from associated agencies.

The chapter began by discussing the issue of how to deal with waste paper in the United States. Recycling is believed to be the solution, but a large percentage of waste paper is still being disposed of in landfills. The use of waste paper as fuel has not been adequately addressed due to the public's preference towards recycling into new products. The concept of using waste paper as fuel until profitable recycling markets are developed may have the potential to help solve current municipal waste and air pollution problems.

The composition of paper was then discussed to assist in determining its acceptability for boiler fuel. The many different types of paper consists of basically the same ingredients: pulp, fillers, and coatings. The majority of these ingredients are organic compounds which should burn very cleanly and completely. The energy content of waste paper represents approximately 60 percent of the energy content of coal.

A general discussion of travelling-grate spreader stoker boilers was included to familiarize one with their operation and to assist in determining the feasibility of burning waste paper in these boilers. The discussion included specific requirements required for acceptable fuels.

The literature review concluded with a discussion of USAF, federal, and state environmental regulations applicable to waste paper derived fuel. The majority of regulations dealing with alternative fuels in coal-fired boilers are located in the Clean Air Act. Many states have been delegated the authority by the Environmental Protection Agency to implement the Clean Air Act. These regulations require some control over waste paper derived fuel but not so much as to discourage attempts at using waste paper as fuel.

III. Methodology

Overview

Currently a vast amount of waste paper is being generated by the American public, and a large percentage of this paper is being disposed of in a dwindling number of landfills. One proposed solution to this problem has been recycling. However, both the technology to recycle low-grade paper and a market for recycled paper products have not been sufficiently developed to prevent the landfilling of large quantities of waste paper. A possible alternative to landfilling waste paper while the markets and technology for its reuse are being developed is processing waste paper for use as fuel in coal-fired boilers.

The Air Force currently does not burn waste paper in its coal-fired boilers. The Air Force recycles specific high grades of paper for which a profitable market exists and disposes of the remaining waste paper in the municipal solid waste stream (Norman, 1992). The purpose of this research is to determine if the waste paper currently being disposed of on Air Force installations can be processed into a technically acceptable, economically feasible fuel for coal-fired boilers.

The majority of information required to determine the technical acceptability and economic feasibility of waste paper derived fuel will be obtained from a literature review and interviews with individuals from appropriate agencies.

A case study involving the burning of waste paper derived fuel in coal-fired boilers at Wright-Patterson AFB will also be conducted to assist in determining the economic feasibility of waste paper derived fuel.

Technical Acceptability

To determine the technical acceptability of waste paper as fuel for coal-fired boilers requires addressing the following questions:

1. What specific characteristics must a substance possess to be suitable for use as fuel in coal-fired boilers?

2. What are the combustion characteristics of waste paper derived fuel, including thermal output and by-products?

3. What are the specific requirements of the Clean Air Act and other applicable laws regarding alternative fuels in coal-fired boilers?

A study of coal-fired boiler literature will be used to determine the general characteristics required for acceptable fuel. A study of the coal-fired boilers at Wright-Patterson AFB will also be conducted to validate the literature review. The specific characteristics to be examined will include the physical characteristics required for a fuel to be compatible with the current feed systems used to supply coal to the boilers. The chemical and combustion characteristics of acceptable fuel will also be examined. These characteristics will include percent moisture, percent volatile matter, percent ash, percent sulfur, heat content, ash fusion temperature, and size.

After determining the specific requirements for alternative fuels in coal-fired boilers the study will examine the characteristics of waste paper derived fuel to determine if it can meet these requirements. The chemical compositions, combustion by-products, and heat content of various types of waste paper will be obtained from literature reviews.

The techniques and equipment required to form the waste paper into an acceptable form for coal-fired boiler fuel will be examined by reviewing literature from a current manufacturer of waste paper processing equipment. The type of equipment examined will include paper shredders and briquetters, a specialized compactor, that will produce a product that meets the parameters for coal-fired boiler fuel.

The specific laws regarding acceptable fuels in coal-fired boilers will be obtained from a literature review of relevant laws and USAF regulations, to include: the Clean Air Act, the Resource Conservation and Recovery Act, and USAF pollution prevention directives. Interviews will also be conducted with environmental regulating authorities concerned with monitoring coal-fired boilers, to include: the Regional Air Pollution Control Authority (RAPCA) who are responsible for issuing coal-fired boiler operating permits to Wright-Patterson AFB. The study will include interviews with RAPCA personnel to determine the specific requirements to obtain an amendment to a current operating permit which

will allow for the burning of waste paper derived fuel in combination with coal.

Economic Feasibility

To determine the economic feasibility of using waste paper derived fuel in coal-fired boilers requires addressing the following questions:

1. What fuel cost savings could be realized if waste paper derived fuel is used to supplement coal fuel?

2. What are the costs associated with processing waste paper derived fuel?

3. What costs are associated with modifications to coal-fired boilers and their operation which will enable the use of waste paper derived fuel?

4. What cost savings will be realized from the decrease in landfill and collection fees as waste paper is used as fuel?

5. What is the availability of acceptable waste paper that can be developed into fuel?

A specific investigative case study involving a steam generating coal-fired boiler at Wright-Patterson AFB will be conducted to determine the economic feasibility of using waste paper as a supplemental fuel. The justification for a specific case study over a generalized study is due to the many site specific costs involved in the economic analysis. Many of the costs, such as landfill fees and coal prices, are dependent on location.

The current fuel costs associated with burning coal will be obtained from the Energy Monitor for the Wright-Patterson Civil Engineering Squadron. The heat content of both coal and waste paper will be determined in the

literature review, and the difference in fuel costs will be calculated using the cost per Btu from coal versus the costs per Btu from waste paper.

The costs associated with preparing waste paper into a suitable form for fuel will be obtained from a manufacturer of waste paper processing equipment. The information collected from the manufacturer to complete the acceptability study will be used to calculate both capital costs and operating costs of the necessary equipment.

The cost savings realized from lower landfill and waste collection fees from burning versus disposing waste paper will be determined by obtaining the current landfill and collection fees paid by Wright-Patterson AFB. The economic feasibility model will assume the amount of waste paper burned will reduce landfill use by a corresponding amount, and that collection fees will also be reduced. The cost of landfilling the ash produced during waste paper combustion will also be considered.

Any costs associated with required modifications to the coal-fired boiler will be discussed in general. These costs will include both fuel feeding modification costs and emission control modification costs. However, due to the possible temporary nature of using waste paper as fuel the goal is to keep these modifications to a minimum.

The availability of waste paper for processing into an acceptable fuel will be determined from a literature review. The literature review will estimate the quantities of waste

paper being generated by the public, and the quantities available for use as fuel.

All of the above cost information will be used to calculate the annual costs or savings associated with waste paper derived fuel. These figures will then be used to determine the net present value of implementing waste paper derived fuel over the life of the project. The economic feasibility model will provide the information needed to determine the amount of waste paper that must be used as fuel to make the waste paper derived fuel venture profitable.

Summary

This chapter outlines the methodology that will be used to determine both the technical acceptability and economic feasibility of processing waste paper for use as fuel in coal-fired boilers. A literature review, interviews with associated organizations, and a case study of a Wright-Patterson AFB coal-fired boiler will be conducted to address both the question of technical acceptability and economic feasibility of waste paper derived fuel.

IV. Evaluation of Technical Acceptability and Economic Feasibility

Overview

This chapter combines information from the literature review along with new data to specifically address the technical acceptability and economic feasibility of using waste paper as fuel in coal-fired boilers on Air Force installations. These two questions are answered by specifically addressing the research questions stated in Chapter III.

Technical Acceptability

The ability of waste paper to be developed into a technically acceptable fuel for coal-fired boilers is determined by first addressing the question of essential characteristics for coal-fired boiler fuels and whether or not waste paper possesses these characteristics. Secondly the ability to process waste paper into an acceptable form for use as fuel is examined. The acceptability section concludes with a discussion of waste paper derived fuel's compliance with applicable environmental laws and regulations.

Waste Paper Fuel Characteristics. The fuel characteristics discussed in this section are applicable to travelling-grate spreader stoker boilers, as this type of boiler represents the majority of coal-fired boilers on Air Force installations. As was discussed in the literature

review, coal must possess characteristics that facilitate both ideal combustion and conveyance from the delivery vehicle to the combustion chamber of the boiler. These characteristics include percent moisture, percent volatile matter, percent ash, ash fusion temperature, percent sulfur, heat or Btu content, and size. This section first examines waste paper to determine if it possesses the above required characteristics for boiler fuels. The processing of waste paper into a form that can be successfully conveyed into the combustion chamber and burned is then discussed.

Moisture Percentage. The maximum moisture percentage of coal is specified to prevent both handling and combustion problems. Too much moisture will cause the coal to stick to conveyor belts and buckets and also lower its heating value. For coal used in Wright-Patterson AFB boilers the maximum moisture percentage is specified to be 5 percent (see Appendix A). Waste paper may contain up to 25 percent moisture (Tillman, 1991:236). This high moisture content reduces the heating value of waste paper, but as is discussed later, waste paper contains a sufficient heat content to be co-fired with coal. This higher moisture content should not cause any handling problems for processed waste paper, and as is discussed later, should aid in the processing of the waste paper into an acceptable form. The tendency for waste paper to absorb water will require its protection from the elements to prevent even higher moisture contents.

Volatile Matter Percentage. The percentage of volatile matter in fuel determines where combustion takes place in the boiler. As stated in the literature review, a high percentage of volatile matter leads to a higher combustion efficiency but also increases the amount of combustion taking place above the fuel bed. An ideal percentage of volatile matter exists that promotes both combustion efficiency and location.

The maximum percentage of volatile matter for dry coal at Wright-Patterson AFB is specified to be 40 percent (see Appendix A). A Washington State Energy Office study determined the average percentage of volatile matter in dried waste paper is 83 percent (Lyons and Kerstetter, 1990:11). This high percentage of volatile matter in paper increases the potential for emissions of incomplete combustion products as the volatiles exit the boiler before they are completely combusted. These products include carbon monoxide (CO), carbon (soot), and polyaromatic hydrocarbons (PAH) (Smith, 1987:265). PAH compounds are of interest because they may possess carcinogenic or mutagenic potential. These PAH compounds are not present in wood; however, they may be formed during incomplete combustion of wood and therefore also paper.

To prevent the emission of incomplete combustion by-products certain modifications may be needed to normal boiler operating procedures. Normal boiler operation requires the addition of air both above and below the

travelling-grate to augment the combustion process. One method of improving combustion of volatile matter above the fuel bed would be to increase the amount of air being pumped into the combustion chamber above the fuel bed (Woodruff and Lammers, 1977:142,148). This additional air should not only improve combustion of the volatile matter, but it should also force the volatile matter back towards the high temperatures of the fuel bed and promote further combustion.

Ash Percentage. As stated in the literature review, both the minimum and maximum percentages of ash in boiler fuels are important. A minimum amount of ash is needed to protect the travelling-grate from the direct heat produced by combustion, but this ash must also be removed from the boiler and disposed of as waste.

The maximum percentage of ash specified for dry coal at Wright-Patterson AFB is 7.0 percent (see Appendix A). The minimum percentage of ash required to protect the grate is 4-6 percent (Woodruff and Lammers, 1977:124). Non-glossy paper has a typical ash content of 12.7 percent and glossy paper has a typical ash content of 23 percent (Tillman, 1991:225).

The higher percentage of ash in paper should not create problems in boiler operation due to the design of the travelling-grate spreader stoker boiler. The design allows for efficient removal of ash from the combustion chamber as the travelling-grate deposits the ash into an ash hopper

after combustion is complete (see Figure 4). However, this additional ash will result in increased disposal costs.

Ash Fusion Temperature. The minimum ash fusion temperature is an important fuel property as it allows for proper ash transport and removal from the boiler. The ash fusion temperature for coal at Wright-Patterson AFB is specified to be at least 2300 degrees Fahrenheit (see Appendix A). The ash fusion temperature for wood, the main ingredient in paper, ranges from 2200-2680 degrees Fahrenheit (Tillman, 1991:90).

As stated in the literature review, the combustion temperature range in the boiler furnace typically ranges from 2200-2400 degrees Fahrenheit. These temperatures may create problems with the ash fusion temperature of waste paper derived fuel. The Chief of Heating Operations at Wright-Patterson AFB revealed that ash fusion problems had resulted during an attempt to burn refuse derived fuel in a coal-fired boiler at Wright-Patterson AFB (Solomon, 1993). This refuse derived fuel, which contains a large percentage of paper, produced large lumps of coagulated ash, termed clinkers, which interfered with proper operation of the boiler.

To prevent similar operating problems during burning of waste paper derived fuel would require strict monitoring of the boiler operating temperature to ensure it does not exceed the ash fusion temperature of waste paper derived fuel or coal. The boiler may need to be operated at reduced

ratings or with increased excess air to lower the furnace temperature and prevent formation of clinkers (Woodruff and Lammers,1977:124).

Sulfur Percentage. The percentage of sulfur in boiler fuel is important because it determines the amount of sulfur dioxide (SO_2) produced. SO_2 is not only a criteria air pollutant, but SO_2 also forms sulfurous acid which corrodes steel components in the boiler.

The typical sulfur percentages for various coals mined in the United States range from 0.36-2.44 percent (see Table 2). The maximum percentage of sulfur specified for Wright-Patterson AFB coal is 1.3 percent (see Appendix A). The typical percentage of sulfur in paper ranges from 0.19 percent for newspaper to 0.23 percent for corrugated boxes (Kaiser, 1975:2). This lower percentage of sulfur makes waste paper an ideal fuel substitute for coal as it would greatly reduce sulfur dioxide emissions.

Heat Content. The energy contained within a fuel, or heat content, allows it to be combusted and provide heat to produce hot water or steam in the boiler. The average heat content for various coals mined in the United States ranges from 6,330-13,600 Btu per pound (see Table 3). The average energy content for waste paper ranges from 8,000 Btu per pound for newspaper to 7,000 Btu per pound for corrugated boxes (see Table 1). The heat content of paper is lower than that of coal due to higher percentages of both

moisture and ash in paper. Neither of these components contribute to the energy produced by a fuel.

This lower energy content in waste paper derived fuel requires larger quantities of waste paper derived fuel to be burned to produce the same amount of energy as coal. However, the successful cocombustion of refuse derived fuel, which has a lower heat content than waste paper, and coal in several boilers has proven that the air and fuel delivery systems in boilers will allow for this adjustment in fuel quantities (Norton and Levine, 1989:775).

Size. The size, shape, and density of a fuel are important in ensuring the fuel can be properly delivered to and combusted in the furnace section of a boiler. To allow existing travelling-grate spreader stoker conveying systems to deliver waste paper derived fuel to the combustion chamber, the fuel must exhibit similar characteristics to the pieces of coal being burned (Solomon, 1993).

Proper fuel size, shape, and density ensure smooth flow of the fuel through the many conveying systems and chutes needed to transport the fuel from the delivery vehicle to the furnace. These characteristics are also very important in ensuring proper distribution of the fuel along the travelling-grate in the furnace (Solomon, 1993).

The fuel is distributed along the travelling-grate by a spinning overthrow rotor (see Figure 5). The speed of the rotor is adjusted to ensure proper distribution of the coal along the grate. To enable waste paper derived fuel to be

cocombusted with coal it must perform like coal when distributed by the overthrow rotor (Solomon, 1993). This similar behavior is dependent upon both similar size and density.

The size of coal specified for Wright-Patterson AFB's boilers was 5 percent maximum retained by a 1.25 inch screen and 15 percent maximum passing through a 0.25 inch screen (see Appendix A). Coal has a specific gravity of approximately 1.3-1.5 which translates into a density of 81.2-93.7 pounds per cubic foot (Killmeyer and others, 1983:88). Therefore, waste paper must be processed into an approximately 1.25 inch diameter shape with a similar density to enable it to be cocombusted with coal in these boilers. The waste paper derived fuel must also possess enough structural integrity to withstand the physical stresses placed on it by conveying and distribution systems. A technique known as agglomeration may be used to form waste paper into the specific shape and density needed for cocombustion with coal (Holley, 1993).

Waste Paper Agglomeration. (Holley, 1993) Agglomeration is the term that Ferro-Tech, Incorporated uses to describe a process of enlarging particles by consolidating them into a larger object. The specific type of agglomeration that is applicable to processing waste paper derived fuel into an acceptable form is designated briquetting.

The briquetting system designed by Ferro-Tech is shown in Figure 12. This system contains a shredder and a hammermill to prepare the waste paper into an acceptable form for processing by the roll briquetter. The roll briquetter uses pressure to deaerate and densify the paper into briquettes. A cut away view of a roll briquetter is shown in Figure 13. The size of the briquettes can be varied, and the system in Figure 12 will produce 1,500 pounds per hour of 1.25 inch diameter briquettes to meet coal-fired boiler fuel requirements.

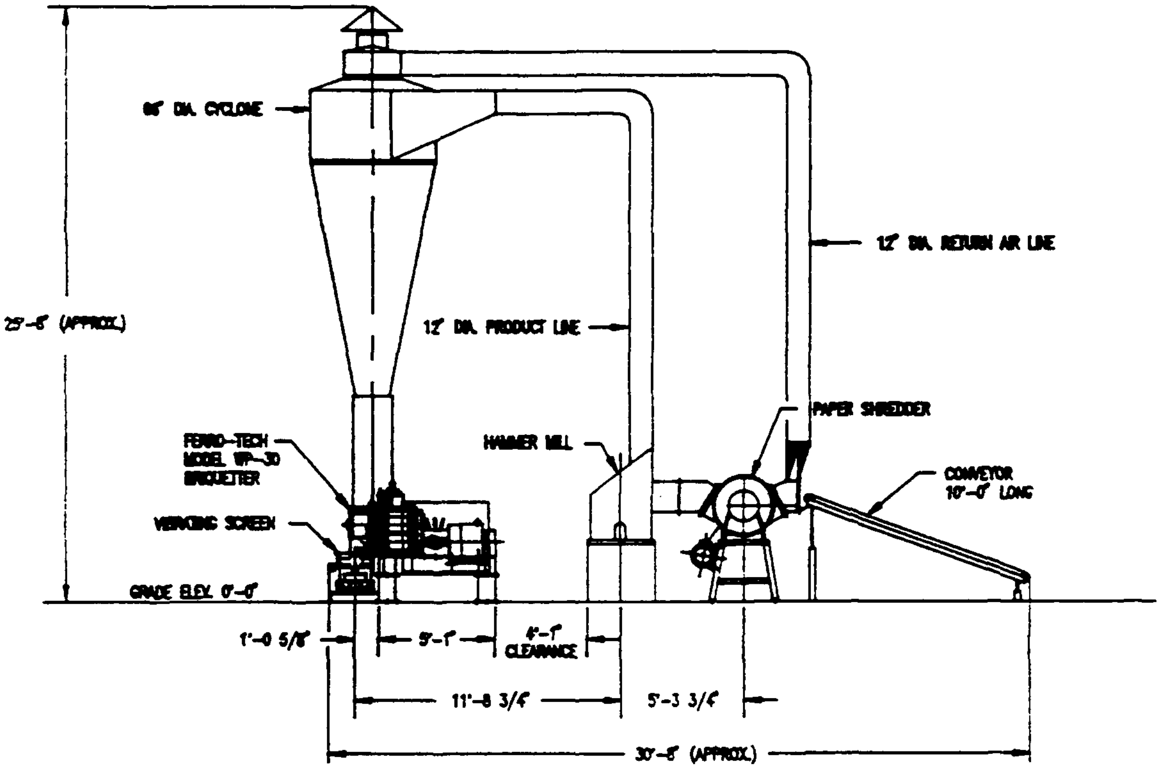

Figure 12. Waste Paper Briquetting System (Holley, 1993)

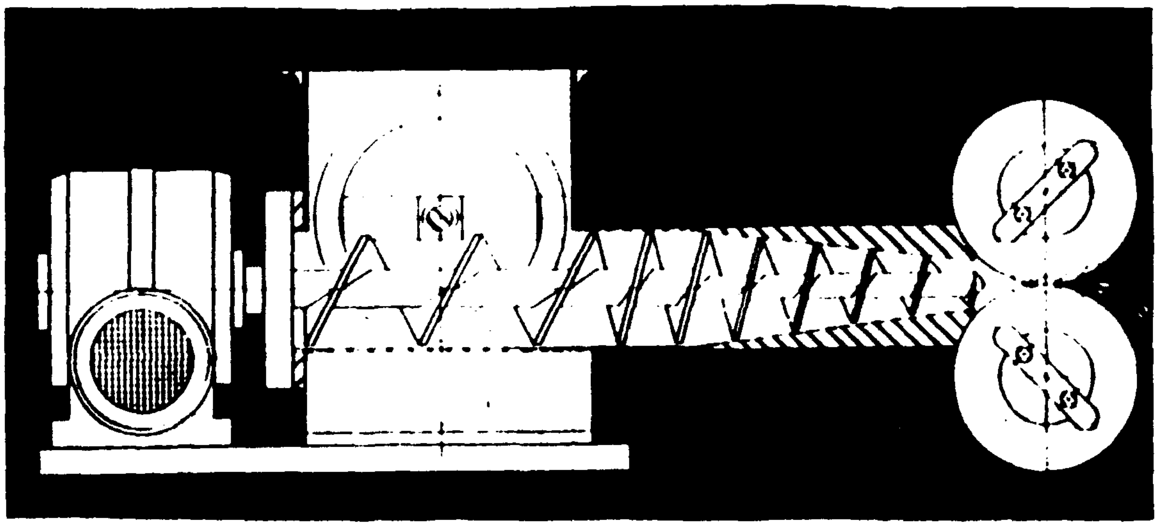

Figure 13. Roll Briquetter (Holley, 1993)

This type of processing does not require the addition of any binders to the waste paper to add structural integrity to the briquettes. The 30 tons of pressure applied by the roll briquetter in combination with the moisture in waste paper are sufficient to form a structurally sound briquette. The specific gravity of the briquettes is approximately 1.25 which translates into 78 pounds per cubic foot. This compares closely to the 81.2-93.7 pounds per cubic foot listed earlier for coal.

In summary, the briquetting process and equipment developed by Ferro-Tech, Incorporated will process waste paper into an acceptable size, shape, and density to allow it to be cocombusted with coal in travelling-grate spreader

stoker boilers. The costs associated with operating this system are discussed in the economic feasibility section of this chapter.

Applicable Law and Regulation Compliance. The two previous sections have proven that waste paper is capable of being processed into a technically acceptable fuel for use in travelling-grate spreader stoker boilers. This acceptability is of little importance if waste paper derived fuel is not capable of complying with the many laws and regulations reviewed in Chapter II concerning the use of alternative fuels in coal-fired boilers. This section reviews these laws and regulations and addresses the compliance issues.

Clean Air Act Compliance. The use of waste paper derived fuel is governed by many sections of the Clean Air Act Amendments of 1990 (CAA of 1990). The specific standards of the act are addressed below.

CAA of 1990 Title IV: Acid Rain. As was stated in the literature review, Title IV is aimed mainly at regulating sulfur dioxide emissions from large electric utility plants. However, the potential for waste paper derived fuel to greatly decrease sulfur dioxide emissions should ensure that its use would be highly encouraged by environmental regulators. Decreasing sulfur dioxide emissions may also benefit bases in air quality non-attainment areas.

CAA of 1990 New Source Performance Standards. As was stated in the literature review the New Source Performance Standards list specific maximum emission levels for particulate matter, sulfur dioxide, and nitrogen oxides in new or modified industrial steam generating units. These standards will affect new and modified boilers on Air Force installations. Modification is defined as any physical change or change in operation which increases the amount of any air pollutant emitted or results in the emission of new air pollutants (Commerce Clearing House, 1990:120).

The use of waste paper derived fuel may create more particulate matter emissions as it contains significantly more ash than coal. Some of this ash will be emitted from the combustion chamber of the boiler as fly ash, and this fly ash may be emitted through stack emissions. As was discussed in the literature review, there are several different types of emission controls in use on coal-fired boilers to control these particulate emissions. An Iowa State University study of several boilers co-firing refuse derived fuel and coal showed mixed results on particulate emission control (Norton and Levine, 1989:779). However, the study stated that when boiler load and fuel percentages were relatively stringent, ash emissions appeared to increase.

As was stated earlier, the cocombustion of waste paper derived fuel and coal will lower sulfur dioxide emissions. This lowering of sulfur dioxide emissions will assist in

meeting new source performance standards for sulfur dioxide emissions. Other options exist for sulfur dioxide control, but as the literature review pointed out, these methods can be very expensive.

The use of waste paper derived fuel may cause an increase in nitrogen oxide emissions due to possible additional air needed to ensure proper combustion. The larger percentage of volatile matter in waste paper may require additional air to ensure complete combustion of the volatiles. Also, excess air may be required to prevent ash fusion temperature problems with waste paper fuel. The nitrogen and oxygen in this excess air can combine to form nitrogen oxides. The most common method of controlling nitrogen oxide emissions is by limiting the amount of air available for combustion. However, as was just stated, this limited air may negatively affect the proper combustion of waste paper derived fuel.

<u>CAA of 1990 Hazardous Air Pollutants</u>. The possibility exists for waste paper combustion to emit several of the 189 toxic air pollutants regulated under the CAA of 1990. An ultimate analysis determines the elemental composition of a substance, and this analysis will assist in determining the by-products from combustion of waste paper. Table 4 contains an ultimate analysis of glossy and non-glossy paper and also an ultimate analysis of coal for comparison purposes.

Table 4

ULTIMATE ANALYSIS OF WASTE PAPER AND COAL FUELS

(% by weight)	Glossy Paper	Non-Glossy Paper	Bituminous Coal
Carbon	43.40	47.30	78.00
Hydrogen	5.30	6.10	5.24
Oxygen	27.50	32.00	7.47
Nitrogen	0.62	1.58	1.23
Sulfur	0.25	0.25	0.95
Chlorine	0.04	0.04	-
Ash	23.00	12.70	7.11

(Tillman, 1991:245; Woodruff and Lammers, 1977:121)

Special attention should be drawn to the presence of chlorine in waste paper. As shown in Table 4, chlorine is found in waste paper but not in coal. The presence of chlorine in fuel can lead to the formation of polychlorinated dioxins and furans during the combustion process (Tillman, 1991:262). These compounds are of high interest not only because of their listing as toxic air pollutants, but also due to the extremely toxic effects they have exhibited in laboratory animals (Clement and others, 1990: 57). The presence of chlorine in waste paper may also lead to the formation of hydrochloric acid, another toxic air pollutant, which has the potential to corrode steel boiler components.

The process in which dioxins and furans are formed is not completely understood, but formation depends on incomplete reactant mixing and low combustion temperature (Clement and others, 1990:62; Tillman, 1991:263).

Maintaining combustion temperatures above 1800 degrees Fahrenheit and providing sufficient excess air to ensure complete mixing and combustion has been shown to control dioxin and furan formation (Tillman, 1991:263-264). As was stated in Chapter II, the typical temperature of a travelling-grate spreader stoker boiler ranges from 2200-2400 degrees Fahrenheit which in conjunction with proper boiler operation should control dioxin and furan formation.

Table 5 lists average concentrations of trace metals contained in both glossy and non-glossy paper, and several of these metals are listed in the toxic air pollutant list. The fate of these trace metals in the combustion process is dependent upon metal volatility temperature, combustion temperature, the presence or absence of chlorine in the combustion system, and the percentage of oxygen present (Tillman, 1991:52). The above conditions determine whether metals end up in bottom ash, fly ash, or volatile emissions. The lack of reported studies and techniques for empirical measurement of the fate of these metals prevents stating specific results concerning trace metal speciation (Tillman, 1991:53).

Table 5

TYPICAL TRACE METALS IN PAPER

Trace Metal	Content (ppm by weight) Glossy Paper	Non-Glossy Paper
Arsenic	3.1	3.3
Barium	285.1	78.9
Beryllium	1.1	1.3
Cadmium	1.1	1.3
Chromium	23.8	37.3
Copper	74.8	40.3
Lead	88.4	621.2
Manganese	61.2	137.6
Mercury	0.3	0.7
Nickel	10.4	15.5
Selenium	3.1	2.9
Strontium	62.4	73.2
Zinc	164.5	227.6

(Tillman, 1991:245; Woodruff and Lammers, 1977:121)

CAA of 1990 Solid Waste Combustion. Section 129 of the CAA of 1990 requires control of particulate matter, sulfur dioxide, hydrogen chloride, nitrogen oxide, carbon monoxide, lead, cadmium, mercury, dioxin, and dibenzofuran emissions from the combustion of solid waste. These regulations may apply to waste paper derived fuel depending on whether it is classified as solid waste fuel or wood fuel. For example, the state of Washington Administrative Code exempts wood fuels from solid waste regulations, and the possibility exists for labeling waste paper derived fuel as wood fuel (Lyons and Kerstetter, 1990:18).

CAA of 1990 Title V: Permits. The operating permits required by Title V of the CAA of 1990 will require

amendments to allow for additional fuel sources. These amendments may include changes to the emissions permitted, fuel sampling required, and emission controls required (Wilson,1993). The permit requirements, as stated in Chapter II, vary from state to state.

Resource Conservation and Recovery Act Compliance. As stated in Chapter II the ash from municipal solid waste incineration is not currently regulated under hazardous waste provisions of the Resource Conservation and Recovery Act (RCRA). The ash produced from coal-fired boilers is also not regulated, and is currently being disposed of in municipal solid waste landfills (Solomon, 1993). The possibility for future regulation of waste ash is very important as waste paper produces 80-280 percent more ash than coal.

The Washington State Energy Office performed an Extraction Procedure (EP) toxicity test of mixed waste paper ash to obtain information which would assist in determining if this ash should be labeled as hazardous waste. The results showed that waste paper ash should not be labeled as a hazardous waste using the EPA Toxicity Test definition (Lyons and Kerstetter, 1990:13). However, Mark Rogoff, Chairman of the Waste-to-Energy Committee of the National Solid Waste Association, believes that the possibility of solid waste ash regulation under RCRA is high (Rogoff, 1992:E-61).

Air Force Policy Directive 19-4, Pollution Prevention, Compliance.

Air Force Policy Directive 19-4 states that Air Force installations will reduce their municipal solid waste disposal by the end of 1997 to 50 percent of the 1992 baseline. To accomplish this drastic reduction in waste disposal will require the use of alternative technologies such as waste paper derived fuel. As was stated earlier, there are large quantities of low grade papers on Air Force installations that are not being recycled and are being disposed of in landfills. Recycling this paper into fuel would help in meeting the guidelines set up by AF Policy Directive 19-4.

Economic Feasibility

The previous section addresses the technical acceptability of waste paper as a supplemental fuel in coal-fired boilers. However, the use of waste paper as fuel is not only an acceptability question, but also a question of economic feasibility. With the ever tightening financial situation the Air Force is facing the use of waste paper derived fuel must be economically feasible to justify its use. This section addresses the economic feasibility of waste paper derived fuel by examining costs and savings involved with collecting, processing, and burning waste paper in coal-fired boilers. An economic analysis model is presented that can be used for any Air Force

installation,. A case study using this model is then presented with specific values for Wright-Patterson AFB.

The economic analysis assumes that no modifications to the boiler, emission controls, or fuel conveying systems are required to enable waste paper derived fuel to be used. These assumptions are based on information from the technical acceptability section, and may not be true in all cases.

Economic Analysis. The first step required in the implementation of waste paper derived fuel is collection of a sufficient quantity of waste paper. As stated in Chapter II, as of 1990, the United States was recycling only 27 percent of the approximately 70 million tons of paper produced each year. In addition, a solid waste management study performed at Wright-Patterson AFB revealed that 20 percent, or 8,200 tons, of the 41,000 tons of solid waste disposed of in landfills in fiscal year 1992 consisted of non-recyclable paper and uncollected recyclable paper (Wright-Patterson AFB, 1993:7-8). As a result there should be sufficient quantities of waste paper for processing into waste paper derived fuel. Additionally, collection costs for this waste paper are assumed to be negligible as organizations can be required to deliver the waste paper to the processing location.

The waste paper processing location should be located adjacent to the coal-fired boiler. The cost analysis includes a 3000 square feet by 27 feet high warehouse to

enclose the waste paper briquetting system (system dimensions, lxwxh, 31 feet by 9 feet by 26 feet) and provide dry storage for waste paper and processed briquettes. The warehouse will include an automatic sprinkling system as required by the 1988 Uniform Fire Code for storage of baled waste paper in excess of 1,000 cubic feet (Lyons and Kerstetter, 1990:29).

The possibility exists that many coal-fired boilers will have existing facilities available for both enclosing the briquetting system and storing the waste paper briquettes. The coal storage silos previously shown in Figure 7 would make an ideal location for storage and protection of briquettes. A possible location for briquetting systems may be facilities containing railroad car coal dumping systems which have become obsolete at many boilers as more coal is delivered by tractor trailer (Gibson, 1993).

The cost analysis also includes maintenance and operation costs for the briquetting system, and labor expenses for one additional employee to operate the briquetting system. The employee's salary is wage grade 5 as this grade was suggested by a solid waste management study for recycling workers (Wright-Patterson AFB, 1993).

A study by the Washington State Energy Office recommends that waste paper briquette fuel should not exceed 50 percent on a heat input basis as this has proven to be the reasonable limit for cocombustion of refuse derived fuel

or wood wastes with coal in spreader stoker type boilers (Lyons and Kerstetter, 1990:32). As stated earlier the Ferro-Tech briquetting system is capable of producing 1,500 pounds of briquettes per hour. Operating the briquetting system 8 hours per day, 5 days per week, would produce 60,000 pounds of briquettes per week. Therefore, the volume of waste paper derived fuel that may be used is a maximum of 50 percent of total boiler heat input, but not to exceed the volume capable of being produced by the briquetting system.

Due to boiler load, and therefore fuel consumption, being seasonal in many locations temporary storage of processed briquettes may be required if the briquetting system is to be operated year round. Year round processing of waste paper briquettes may require storing briquettes during low fuel demand periods for use during high demand periods. The warehouse described earlier should provide sufficient storage space for excess briquettes.

The model includes a compensation factor for the difference in heating values between coal and waste paper derived fuel. The heating value for waste paper is assumed to be 8,000 Btu/pound, the value for newspaper (see Table 1). The heating value for coal is assumed to be 12,450 Btu/pound, the value for bituminous Ohio coal (see Table 3).

The final cost consideration is for waste disposal. A savings will result from less waste paper being disposed of as solid waste in landfills. However, waste paper derived fuel creates more ash than coal and will therefore increase

boiler ash disposal fees. Nevertheless, as a result of volume reduction due to combustion there will be a net savings in waste disposal fees. The factor used to compensate for increased ash production is based on 7.11 percent ash for bituminous coal and 12.85 percent ash for a combination of glossy and non-glossy waste papers (see Table 4).

Cost Calculations. The cost calculations in this study are performed using guidance from a Defense Energy Program Policy Memorandum issued for prioritizing projects in the Energy Conservation Investment Program using life cycle cost analysis (Department of Defense, 1992). The analysis life will be 20 years as recommended for boiler plant dual fuel conversions. However, different life spans can be examined by simply substituting the expected life span in the appropriate formulas. The memorandum also requires the use of a 10 percent discount rate and 0 percent inflation. Straight line depreciation assuming zero salvage value is used to expense capitol costs. The costs and savings discussed above are first listed, and formulas for performing a life cycle cost analysis follow. The costs and savings are annualized to facilitate the calculation of net present value in the life cycle analysis. Specific dollar values are listed for costs and savings that are relatively independent of location, and cost references are included. Other costs, for example solid waste disposal fees, will need to be determined for each specific location.

Costs/Savings.

1. Capitol Costs:

   a. Waste Paper Briquetting System- Delivered cost for Ferro-Tech, Incorporated system shown in Figure 12

      Initial Cost- $325,000 (Holley, 1993)

      Annualized Cost- Using straight line depreciation with no salvage value

      $$\frac{\text{Initial Cost}}{\text{life span}} = \text{Annual expense}$$

      $325,000/20 years=$16,250/year

   b. 3,000 square foot warehouse with automatic sprinkling system- Metal siding on steel frame warehouse with wet, exposed sprinkler system

      Initial Cost- $153,750 (Saylor, 1991:116,191)

      Annualized Cost- Using straight line depreciation with no salvage value

      $$\frac{\text{Initial Cost}}{\text{life span}} = \text{Annual expense}$$

      $153,750/20 years=$7688/year

2. Operating Costs:

   a. Labor- 1 wage grade 5 employee

      Annual- $21,793 per year (Wright-Patterson AFB, 1993)

   b. Electricity- For briquetting system only based on $0.03 per kwH

      Annual- $0.45 per ton of briquettes (Holley, 1993)

   c. Maintenance- Expected replacement costs for wear items on briquette system

      Annual- $0.35 per ton of briquettes (Holley, 1993)

3. Waste Disposal Savings/Costs:

a. Waste Paper Landfill Disposal Savings-

Annual- waste paper combusted X solid waste disposal fee

b. Additional Ash Disposal Costs-

Annual-

$$\text{waste paper combusted} \times \frac{12.85\%\ \text{ash waste paper}}{7.11\%\ \text{ash coal}} \times \text{ash disposal fee}$$

4. Fuel Savings:

a. Annual Coal Purchase Savings-

$$\text{waste paper combusted} \times \frac{8{,}000\ \text{Btu/lb waste paper}}{12{,}450\ \text{Btu/lb coal}} \times \text{Coal Cost}$$

Life Cycle Cost Analysis. This analysis uses a two step process to calculate the net present value of the costs and savings stated above over a twenty year period. Due to the assumption of zero inflation, the analysis calculates the first year cost/savings and uses this same value over the twenty year life span in combination with the discount rate to calculate the net present value.

Step 1. Calculate Annual Cost/Benefit

Annual Cost/Benefit= -Annualized Briquetting System Costs
-Annualized Warehouse Costs
-Annual Labor Costs
-Annual Electricity Costs
-Annual Maintenance Costs
-Annual Fly Ash Disposal Costs
+Annual Waste Paper Disposal Savings
+Annual Fuel Savings

Step 2. Calculate Present Value Cost/Benefit- Bring above annual costs/benefits for the 20 year life cycle back to present value using the following formula:

$$\text{Present Value} = \frac{\text{Future Value}}{(1 + \text{discount rate})^{\text{year}}}$$

As stated earlier, the discount rate that should be used is 10 percent. A positive net present value indicates that the benefits of waste paper derived fuel outweigh the costs, and a negative net present value indicates that the costs outweigh the benefits.

Wright-Patterson Air Force Base Case Study. This case study uses the above costs/savings and life cycle cost analysis formulas with specific values for Wright-Patterson Air Force Base to determine the economic feasibility of using waste paper derived fuel in a coal-fired boiler plant at Wright-Patterson Air Force Base, Ohio. The boiler plant examined, Building 1240, contains three 152 MMBtu (152 million Btu per hour) travelling-grate spreader stoker boilers. The average annual coal use for this plant over the past four years has been 29,724 tons (Solomon, 1993). This volume of coal will enable the briquetting system to be operated 40 hours per week (1560 tons of briquettes per year), and still be far below the 50 percent maximum heat input recommended for waste paper derived fuel.

Costs/Savings:

1. Capitol Costs

   a. Waste Paper Briquetting System-

      Annualized Cost- $16,250/year

   b. Warehouse with automatic sprinkling system-

      Annualized Cost- $7688/year

2. Operating Costs

   a. Labor- $21,793/year

   b. Electricity- based on Wright-Patterson billing rate of $0.045/kwH (Roth, 1993)

$$\frac{\$0.45}{\text{ton briquettes}} \times \frac{\$0.045/\text{kwH}}{\$0.03/\text{kwH}} \times \frac{1560 \text{ tons briquettes}}{\text{year}} = \frac{\$1053}{\text{year}}$$

   c. Maintenance-

$$\frac{\$0.35}{\text{ton briquettes}} \times \frac{1560 \text{ tons briquettes}}{\text{year}} = \frac{\$546}{\text{year}}$$

3. Waste Disposal Savings/Costs

   a. Waste Paper Landfill Disposal Savings- (Wright-Patterson AFB, 1993:D-2)

$$1560 \text{ tons waste paper} \times \frac{\$40}{\text{ton}} \text{ solid waste disposal costs} = \frac{\$62,400}{\text{year}}$$

   b. Additional Ash Disposal Costs- (Wright-Patterson AFB, 1993:D-2)

$$\text{1560 tons briquettes} \times \frac{12.85\% \text{ ash paper}}{7.11\% \text{ ash coal}} \times 12.85\% \text{ ash waste paper} \times \frac{\$40}{\text{ton}} \text{ ash disposal}$$

$$= \frac{\$14,492}{\text{year}}$$

4. Fuel Savings

   a. Annual Coal Savings- (Brock, 1993)

$$\text{1560 tons briquettes} \times \frac{8,000 \text{ Btu/lb paper}}{12,450 \text{ Btu/lb coal}} \times \frac{\$47.29}{\text{ton coal}} = \frac{\$47,404}{\text{year}}$$

Life Cycle Analysis:

Step 1. Calculate Annual Cost/Benefit

Annual Cost/Benefit= -Annualized Briquetting System Costs
-Annualized Warehouse Costs
-Annual Labor Costs
-Annual Electricity Costs
-Annual Maintenance Costs
-Annual Fly Ash Disposal Costs
+Annual Waste Paper Disposal Savings
+Annual Fuel Savings

= -\$16,250
-\$7688
-\$21,793
-\$1053
-\$546
-\$14,492
+\$62,400
+\$47,404

= +\$47,982

Step 2. Calculate Present Value Cost/Benefit-

$$\text{Present Value} = \frac{\text{Future Value}}{(1 + \text{discount rate})^{\text{year}}}$$

$$= \frac{\$47{,}982}{(1 + 10\%)^{\text{year}}} \quad \text{(where year= 1-20)}$$

TABLE 6

NET PRESENT VALUE CALCULATION RESULTS

Year	Present Value ($)
1	43,620
2	39,654
3	36,050
4	32,772
5	29,793
6	27,085
7	24,622
8	22,384
9	20,349
10	18,499
11	16,817
12	15,289
13	13,899
14	12,635
15	11,487
16	10,442
17	9,493
18	8,630
19	7,845
20	7,132

Total Net Present Value: $408,497

The positive net present value suggests that implementing the use of waste paper derived fuel at Wright-Patterson Air Force Base is economically feasible as it would result in a net savings of over $400,000 during the 20 year life of the project. The assumption of a twenty year life span is an important factor in this economic analysis as it allows for capital expenses to be depreciated over a 20 year period of time. However, as was stated earlier the use of waste paper derived fuel may only be temporary until the paper recycling market improves. The above formulas can be manipulated to calculate the minimum time that waste paper derived fuel

must be used to at least break even, that is to recoup capital expenses. Using the above data for Wright-Patterson AFB reveals a minimum break even period of 7 years.

The quantity of waste paper processed into fuel each year is also an important factor in the economic analysis as it represents a major benefit in reducing fuel and landfill disposal costs. The 1560 tons of waste paper used in this case study should be available for use at Wright-Patterson AFB, but a concerted effort will have to be made to ensure that it is collected and delivered to the boiler plant for processing.

Summary

This chapter has reviewed both the technical acceptability and economic feasibility of using waste paper derived fuel in travelling-grate spreader stoker boilers. It was shown that waste paper exhibits many characteristics that make it technically acceptable for use as fuel. These characteristics include an acceptable heat content and the ability to be processed into an acceptable form. However, waste paper possesses some characteristics that may detract from its use as fuel. The large percentage of volatile matter in waste paper may create excess air emissions due to incomplete combustion. Waste paper derived fuel may create excess nitrous oxide emissions due to additional air needed to ensure proper combustion. Waste paper also contains chlorine which may result in the formation of

polychlorinated dioxins and furans if combustion is not sufficiently controlled. The presence of chlorine in waste paper may also produce hydrochloric acid which will corrode steel boiler components. The final problem associated with waste paper derived fuel was the presence of heavy metals that may cause future regulation of the ash as hazardous waste and may produce toxic air emissions.

The economic feasibility of waste paper derived fuel was discussed and a model presented to determine economic feasibilities on a case by case basis. The use of the model on a boiler plant at Wright-Patterson AFB showed a strong economic justification for implementing the use of waste paper derived fuel over a twenty year period. However, as was stated earlier, the use of waste paper derived fuel may only be temporary in nature, and determining the expected time waste paper derived fuel will be used is very important in calculating the economic feasibility. The importance of determining the amount of waste paper that exists for processing into fuel was also discussed.

V. Conclusions and Recommendations for Further Research

Conclusions

This research revealed solid waste disposal and air pollution problems currently confronting not only the Air Force but the entire country. The necessity of addressing both of these problems was made clear, and the use of waste paper derived fuel in coal-fired boilers was examined as a possible alternative to assist in solving these problems.

A literature review was conducted to provide the needed information for examining the feasibility of using waste paper derived fuel on Air Force installations. This information included the condition of the current waste paper recycling situation, the composition and combustion characteristics of waste paper, a description of travelling-grate spreader stoker boilers and their operation, and a review of environmental laws and regulations concerning waste paper derived fuel.

The literature review revealed little information on previous implementations of waste paper derived fuel mainly due to the public's preference towards recycling paper into new products. However as of 1990, only 27 percent of the paper in the United States was being recycled. The review revealed the majority of regulations concerning waste paper derived fuel are in the Clean Air Act of 1990. The Air Force has also issued guidance relevant to waste paper

derived fuel in a Pollution Prevention Policy Directive concerning solid waste disposal.

Following the literature review, the study addressed waste paper derived fuel from both a technical acceptability and an economic feasibility point of view. The study revealed that waste paper possessed characteristics suitable for a technically acceptable coal-fired boiler fuel. However, the study also discovered waste paper derived fuel exhibits several characteristics that may detract from its implementation. These detractions include the possibility of increased volatile emissions, increased nitrous oxide emissions, dioxin and furan emissions, formation of hydrochloric acid, and the presence of heavy metals in both ash and emissions. The current lack of sufficient data regarding waste paper combustion needs to be addressed before actually implementing the use of waste paper derived fuel.

The economic feasibility of waste paper derived fuel was addressed due to the need for economically justifying projects in today's ever tightening financial situation. The economic analysis model developed can be used for any installation, and was used to examine the life cycle costs of waste paper derived fuel implementation at Wright-Patterson AFB. The results from this case study presented strong economic justification for implementing the use of waste paper derived fuel as a net present benefit of $408,497 was calculated over the twenty year life of the

project. The importance of determining the time period over which waste paper derived fuel will be used and the amount of waste paper processed was emphasized to ensure the project at least breaks even from an economic viewpoint.

In conclusion, there are still some technical questions that must be answered before implementing the use of waste paper derived fuel. However, the economics of waste paper derived fuel are fairly clear in that it will probably save money. In my opinion, the probability is high that waste paper derived fuel represents a step in the right direction towards solving the current solid waste and air pollution problems facing the country. The Air Force has a unique opportunity to be a leader in implementing this technology as it is both a large producer of waste paper and an owner/operator of coal-fired boilers. I believe the Air Force should take a very close look at taking advantage of this opportunity to once again be a leader in the environmental field.

Recommendations for Further Research

This study revealed the need for further research in two specific areas. The first area is the need for further information concerning the combustion of waste paper. The actual air emissions and fate of heavy metals from waste paper combustion in coal-fired boilers are not known, and these factors are an important consideration in determining the feasibility of waste paper derived fuel.

Further research on paper recycling also needs to be accomplished to determine why the current market is in such poor condition. As was stated earlier, the use of waste paper derived fuel may only be temporary measure until the paper recycling market is strengthened. The Air Force is a very large consumer of paper, and it probably has the ability to influence the recycling market. However, the environmental and economic consequences of paper recycling are currently not clear.

Appendix A- Coal Specifications, Wright-Patterson AFB

SECTION B
SCHEDULE OF SUPPLIES

DLA600 -90-B-0015

FB230091709300/16 Jun 89 LINE ITEM NO. 0005. (This is alternate of Line Item No. ________.)

INSTALLATION: 2750 CES/DEU - Wright-Patterson AFB, OH 45433-5000

RAILHEAD AND SERVING RAILROAD, if applicable: N/A

TRANSPORTATION EQUIPMENT FOR THIS ITEM: Truck

OFFERED PRICES SHALL BE PER NET TON: Delivered to destination by truck and unloaded as directed.* All loads will be covered with a tarpaulin or a government-approved substitute.

COAL SIZE: 1¼" X ¼", Oil Treated (See Clause M30(c)

MINIMUM SPECIFICATIONS QUALITY REQUIRED:

Moisture, as received	% Max. 5.0	B.T.U., dry	Min.	14,000
Volatile Matter, dry	% Max. 40.0	A.S.T., degrees F	Min.	2300 (H = ½ W)
Ash, dry	% Max. 7.0	F.S.I.		
Sulfur, dry	% Max. 1.3 Min. .85	Hardgrove Grind. Min.		

Screen Size:		Max. % Retained On	Max. % Passing Through
1¼"	R.H. Screen	5.0	
¼"	R.H. Screen		15.0

TOTAL ESTIMATED REQUIREMENT (NET TONS): 40,000

ADDITIONAL QUANTITY RESERVED, if applicable (NET TONS): See Clause L21.02

NOTE: Offers are solicited only for the unreserved quantity. As stated in Clause L21.02, if the reservation does not result in a contract with the Small Business Administration, this item will be negotiated with the applicable bidders under this solicitation in accordance with the provisions of the clause. Monthly requirements for the reserved quantity will be approximately the same as the estimated monthly requirements below.

ESTIMATED MONTHLY REQUIREMENTS (NET TONS): 19 90 | JAN | FEB | MAR

APR 3,500	MAY 2,000	JUN 1,500	JUL 1,000	AUG 1,000	SEP 1,500
OCT 2,500	NOV 3,500	DEC 6,500	19 91 JAN 6,500	FEB 5,500	MAR 5,000
APR	MAY	JUN	JUL	AUG	SEP
OCT	NOV	DEC			

MAXIMUM QUANTITY CONTRACTOR SHALL BE OBLIGATED TO FURNISH (NET TONS): 40,000

CONTRACTOR SHALL NOT BE REQUIRED TO MAKE ANY DELIVERIES UNDER THIS ITEM AFTER: 91 Apr 30

MAXIMUM ORDER THIS ITEM (NET TONS): 6,500 per month.
NOTE: See Clause I86.02 DELIVERY ORDER LIMITATIONS.

I211(F) ORDERING (APR 1984)

(a) Any supplies and services to be furnished under this contract shall be ordered by issuance of delivery orders by the individuals or activities designated in the Schedule. Such orders may be issued from 01 Apr 90 through 31 Mar 91.

(b) All delivery orders are subject to the terms and conditions of this contract. In the event of conflict between a delivery order and this contract, the contract shall control.

(c) If mailed, a delivery order is considered "issued" when the Government deposits the order in the mail. Orders may be issued orally or by written telecommunications only if authorized in the schedule. (FAR 52.216-18)

THE FOLLOWING SPACE IS RESERVED FOR DFSC USE.

HANDLING COSTS, if applicable (PER NET TON: Rail $ ________ Truck: $ ________
NOTE: See Clause M31 ALTERNATE LINE ITEMS.

* Bidders are urged to ascertain method and locations of unloading by contacting the responsible official at the using activity prior to submitting bids. (AC513) 257-4103.

DFSC Form 6.37-S, Jun 89
(Supersedes Dec 85 Edition)

Appendix B- Toxic Air Pollutants

CAS Number	Chemical Name
75070	Acetaldehyde
60355	Acetamide
75058	Acetonitrile
98862	Acetophenone
53963	2-Acetylaminofluorene
107028	Acrolein
79061	Acrylamide
79107	Acrylic acid
107131	Acrylonitrile
107051	Allyl chloride
92671	4-Aminobiphenyl
62533	Aniline
90040	0-Anisidine
1332214	Asbestos
71432	Benzene (including benzene from gasoline)
92875	Benzidine
98077	Benzotrichloride
100447	Benzyl chloride
92524	Biphenyl
117817	Bis(2-ethylhexyl)phthalate (DEHP)
542881	Bis(chloromethyl)ether
75252	Bromoform
106990	1,3-Butadiene
156627	Calcium cyanamide
105602	Caprolactam
133062	Captan
63252	Carbaryl
75150	Carbon disulfide
56235	Carbon tetrachloride
463581	Carbonyl sulfide
120809	Catechol
133904	Chloramben
57749	Chlordane
7782505	Chlorine
79118	Chloroacetic acid

532274	2-Chloroacetophenone
108907	Chlorobenzene
510156	Chlorobenzilate
67663	Chloroform
107302	Chloromethyl methyl ether
126998	Chloroprene
1319773	Cresols/Cresylic acid (isomers and mixture)
95487	o-Cresol
108394	m-Cresol
106445	p-Cresol
98828	Cumene
94757	2,4-D, salts and esters
3547044	DDE
334883	Diazomethane
132649	Dibenzofurans
96128	1,2-Dibromo-3-chloropropane
84742	Dibutylphthalate
106467	1,4-Dichlorobenzene(p)
91941	3,3-Dichlorobenzidene
111444	Dichloroethyl ether (Bis(2-chloroethyl)ether)
542756	1,3-Dichloropropene
62737	Dichlorvos
111422	Diethanolamine
121697	N,N-Diethyl aniline (N,N-Dimethylaniline)
64675	Diethyl sulfate
119904	3,3-Dimethoxybenzidine
60117	Dimethyl aminoazobenzene
119937	3,3-Dimethyl benzidine
79447	Dimethyl carbamoyl chloride
68122	Dimethyl formamide
57147	1,1-Dimethyl hydrazine
131113	Dimethyl phthalate
77781	Dimethyl sulfate
534521	4,6-Dinitro-o-cresol, and salts
51285	2,4-Dinitrophenol
121142	2,4-Dinitrotoluene
123911	1,4-Dioxane (1,4-Diethyleneoxide)
122667	1,2-Diphenylhydrazine
106898	Epichlorohydrin (1-Chloro-2,3-epoxypropane)
106887	1,2-Epoxybutane
140885	Ethyl acrylate
100414	Ethyl benzene
51796	Ethyl carbamate (Urethane)
75003	Ethyl chloride (Chloroethane)
106934	Ethylene dibromide (Dibromoethane)

107062	Ethylene dichloride (1,2-Dichloroethane)
107211	Ethylene glycol
151564	Ethylene imine (Aziridine)
75218	Ethylene oxide
96457	Ethylene thiourea
75343	Ethylidene dichloride (1,1-Dichloroethane)
50000	Formaldehyde
76448	Heptachlor
118741	Hexachlorobenzene
87683	Hexachlorobutadiene
77474	Hexachlorocyclopentadiene
67721	Hexachloroethane
822060	Hexamethylene-1,6-diisocyanate
680319	Hexamethylphosphoramide
110543	Hexane
302012	Hydrazine
7647010	Hydrochloric acid
7664393	Hydrogen fluoride (Hydrofluoric acid)
123319	Hydroquinone
78591	Isophorone
58899	Lindane (all isomers)
108316	Maleic anhydride
67561	Methanol
72435	Methoxyclor
74839	Methyl bromide (Bromomethane)
74873	Methyl chloride (Chloromethane)
71556	Methyl chloroform (1,1,1-Trichloroethane)
78933	Methyl ethyl ketone (2-Butanone)
60344	Methyl hydrazine
74884	Methyl iodide (iodomethane)
108101	Methyl isobutyl ketone (Hexone)
624839	Methyl isocyanate
80626	Methyl methacrylate
1634044	Methyl tert butyl ether
101144	4,4-Methylene bis(2-chloroaniline)
75092	Methylene chloride (Dichloromethane)
101688	Methylene diphenyl diisocyanate (MDI)
101779	4,4-Methylenedianiline
91203	Naphthalene
98953	Nitrobenzene
92933	4-Nitrobiphenyl
100027	4-Nitrophenol
79469	2-Nitropropane
684935	N-Nitroso-N-methylurea
62759	N-Nitrosodimethylamine
59892	N-Nitrosomorpholine

56382	Parathion
82688	Pentachloronitrobenzene (Quintobenzene)
87865	Pentachlorophenol
108952	Phenol
106503	p-Phenylenediamine
75445	Phosgene
7803512	Phosphine
7723140	Phosphorus
85449	Phthalic anhydride
1336363	Polychlorinated biphenyls (Aroclors)
1120714	1,3-Propane sultone
57578	beta-Propiolactone
123386	Propionaldehyde
114261	Propoxur (Baygon)
78875	Propylene dichloride (1,2-Dichloropropane)
75569	Propylene oxide
75558	1,2-Propylenimine (2-Methyl aziridine)
91225	Quinoline
106514	Quinone
100425	Styrene
96093	Styrene oxide
1746016	2,3,7,8-Tetrachlorodibenzo-p-dioxin
79345	1,1,2,2-Tetrachloroethane
127184	Tetrachloroethylene (Perchloroethylene)
7550450	Titanium tetrachloride
108883	Toluene
95807	2,4-Toluene diamine
584849	2,4-Toluene diisocyanate
95534	o-Toluidine
8001352	Toxaphene (chlorinated camphene)
120821	1,2,4-Trichlorobenzene
79005	1,1,2-Trichloroethane
79016	Trichloroethylene
95954	2,4,5-Trichlorophenol
88062	2,4,6-Trichlorophenol
121448	Triethylamine
1582098	Trifluralin
540841	2,2,4-Trimethylpentane
108054	Vinyl acetate
593602	Vinyl bromide
75014	Vinyl chloride
75354	Vinylidene chloride (1,1-Dichloroethylene)
1330207	Xylenes (isomers and mixture)
95476	o-Xylenes
108383	m-Xylenes
106423	p-Xylenes

0 . . . . Antimony Compounds
0 . . . . Arsenic Compounds
(inorganic including arsine)
0 . . . . Beryllium Compounds
0 . . . . Cadmium Compounds
0 . . . . Chromium Compounds
0 . . . . Cobalt Compounds
0 . . . . Coke Oven Emissions
0 . . . . Cyanide Compounds[1]
0 . . . . Glycol ethers[2]
0 . . . . Lead Compounds
0 . . . . Manganese Compounds
0 . . . . Mercury Compounds
0 . . . . Fine mineral fibers[3]
0 . . . . Nickel Compounds
0 . . . . Polycyclic Organic Matter[4]
0 . . . . Radionuclides (including radon)[5]
0 . . . . Selenium Compounds

Note: For all listings above which contain the word "compounds" and for glycol ethers, the following applies: Unless otherwise specified, these listings are defined as including any unique chemical substance that contains the named chemical (i.e., antimony, arsenic, etc.) as part of that chemical's infrastructure.

OhioEPA

State of Ohio Environmental Protection Agency

PERMIT TO OPERATE AN AIR CONTAMINANT SOURCE

Date of Issuance 08/03/90

Application No 0829700199B006

Effective Date 08/03/90

Permit Fee $270

This document constitutes issuance to

WRIGHT-PATTERSON AFB BUILDING 31240
WPAFB
BATH OHIO 45433

of a permit to operate for

152 MMBTU I.B.W. COAL-FIRED BOILER
BOILER #6

The following terms and conditions are hereby expressly incorporated into this permit to operate:

1 This permit to operate shall be effective until 08/02/93
You will be contacted approximately six months prior to this date regarding the renewal of this permit. If you are not contacted, please write to the appropriate Ohio EPA field office.

2 The above-described source is and shall remain in full compliance with all applicable State and federal laws and regulations and the terms and conditions of this permit.

3 Prior to any modification of this source, as defined in rule 3745-31-01 of the Ohio Administrative Code (OAC), a permit to install must be granted by the Ohio EPA pursuant to OAC Chapter 3745-31.

4 The Director of the Ohio EPA or an authorized representative may, subject to the safety requirements of the permit holder, enter upon the premises of this source at any reasonable time for purposes of making inspections, conducting tests, examining records or reports pertaining to any emission of air contaminants, and determining compliance with any applicable State and federal air pollution laws and regulations and the terms and conditions of this permit.

5 A permit fee in the amount specified above must be remitted within 15 days from the issuance date of this permit.

6 Any transferee of this permit shall assume the responsibilities of the prior permit holder. The appropriate Ohio EPA field office must be notified in writing of any transfer of this permit.

7 This source and any associated air pollution control system(s) shall be maintained regularly in accordance with good engineering practices in order to minimize air contaminant emissions. Any malfunction of this source or any associated air pollution control system(s) shall be reported immediately to the appropriate Ohio EPA field office in accordance with OAC rule 3745-15-06. Except as provided in that rule, any scheduled maintenance or malfunction necessitating the shutdown or bypassing of any air pollution control system(s) shall be accompanied by the shutdown of this source.

8 Any unauthorized or emergency release of an air contaminant from this source which, due to the toxic or hazardous nature of the material, may pose a threat to public health, or otherwise endanger the safety or welfare of the public, shall be reported immediately to the appropriate Ohio EPA field office (during normal business hours) or to the Ohio EPA's Emergency Response Group (1-800-282-9378). (Additional reporting may be required pursuant to the federal Comprehensive Environmental Response, Compensation, and Liability Act.)

9 The appropriate Ohio EPA field office is:

REGIONAL AIR POLLUTION CONTROL AGENCY
451 W. THIRD ST.
DAYTON, OH 45422 (513) 225-4437

10 ☒ If this term and condition is checked the permit holder is subject to the attached special terms and conditions

OHIO ENVIRONMENTAL PROTECTION AGENCY

Richard L Shank

Director

EPA-3834

APPLICATION NUMBER: 0829700199 B006

FACILITY NAME: Wright-Patterson AFB Building 31240

EQUIPMENT DESCRIPTION: 152 MMBTU I.B.W. Coal-Fired Boiler

COMPANY ID: Boiler #6

SPECIAL TERMS AND CONDITIONS

1. Approval to operate the above identified source is hereby granted subject to the conditions expressed herein and consistent with the materials and data included in the application filed by the company. Any departure from the conditions of this approval or the terms expressed in the application must receive prior written authorization of the local air agency (Regional Air Pollution Control Agency) and the Ohio Environmental Protection Agency.

2. The following rule(s) of the Ohio Administrative Code establish the applicable emission limitations and/or control requirements for this source: 3745-31-05, 3745-17-10, and 3745-17-07. (This condition in no way limits the applicability of other requirements of the Ohio Administrative Code to this source.)

3. The mass emissions from this source shall not exceed the following: 0.10 pound of particulate emissions per million BTU actual heat input; and 2.00 pounds of sulfur dioxide emissions per million BTU actual heat input.

4. Visible emissions from this source shall not exceed the limits specified in OAC rule 3745-17-07(A) and (B) except during the following:

   i) It shall be deemed not to be a violation of this permit where the presence of uncombined water is the only reason for failure of an emission to meet the requirements of this permit;

   ii) The start-up of this source until the exhaust gases have achieved a temperature of two hundred fifty (250) degrees fahrenheit at the inlet of the electrostatic precipitator; and

   iii) The shutdown of this source after the temperature of the exhaust gases have dropped below two hundred fifty (250) degrees fahrenheit at the inlet of the electrostatic precipitator.

5. For the upgrading (and replacement, if necessary) of inadequate existing opacity monitoring and recording equipment to meet the requirements of 40 CFR Part 60.13.

(CONTINUED)

Within 90 days of the effective date of this permit, this facility shall upgrade and modify its existing equipment to continuously monitor and record the opacity of the particulate emissions from this source. The modifications and upgrading shall be performed in such a manner as to cause the continuous monitoring and recording equipment to comply with the requirements specified in 40 CFR Part 60.13.

Within 30 days after the upgrading of the continuous monitoring and recording equipment is complete, this facility shall conduct a performance specification test of such equipment pursuant to Section 3704.03(I) of the Ohio Revised Code and 40 CFR Part 60, Appendix B, Performance Specification Test 1. Personnel from the Ohio EPA field office shall be permitted to witness the performance specification test, and 2 copies of the test results shall be submitted to the Ohio EPA field office within 30 days after the test is completed.

In the event the performance test demonstrates that the upgraded continuous monitoring and recording equipment is unable to comply with the requirements specified in 40 CFR Part 60.13, this facility shall, within 60 days after the test is completed, submit a plan and schedule to install and performance test new continuous monitoring and recording equipment which are capable of complying with the applicable requirements specified in 40 CFR Part 60.13. In addition to demonstrating compliance with the applicable requirements specified in 40 CFR Part 60.13, any new continuous opacity monitoring system shall be designed so that a performance audit of the system's operation can be conducted pursuant to the procedures specified in U.S. EPA document 340/1-83/010, "Performance Audit Procedures for Opacity Monitors."

Following the completion of an acceptable performance specification test of either the upgraded or new opacity monitoring and recording equipment, and pursuant to 40 CFR Parts 60.7 and 60.13(h), this facility shall submit reports on a quarterly basis to the Ohio EPA field office documenting all instances of opacity values in excess of the limitations specified in OAC rule 3745-17-07 or any limitations specified in the terms and conditions of this permit. These quarterly excess emission reports shall be submitted by February 1, May 1, August 1, and November 1 of each year and shall address the data obtained during the previous calendar quarters.

(CONTINUED)

6. This facility shall collect representative grab samples of the coal burned in this source daily. Each sample shall be collected from the coal conveyor belt. The coal sampling shall be performed in accordance with ASTM method D2234 Collection of a Gross Sample of Coal. At the end of each calendar month, all of the grab samples which were collected during that calendar month shall be combined into one composite sample.

   This facility shall also record the total quantity of coal burned in this source during each calendar day.

   Each monthly composite of sample of coal shall be analyzed for ash content (percent), sulfur content (percent), and heat content (Btu/pound of coal). The analytical methods for ash content, sulfur content, and heat content shall be ASTM method D3174, Ash in the Analysis of Coal and Coke, ASTM method D3177, Total Sulfur in the Analysis Sample of Coal and Coke, and ASTM method D2015, Gross Calorific Value of Solid Fuel by the Adiabatic Bomb Calorimeter, respectively. Alternatve, equivalent methods may be used upon written approval by the Regional Air Pollution Control Agency.

   Monthly reports concerning the quality and quantity of the coal burned in this source shall be submitted to the Regional Air Pollution Control Agency. These reports shall include the following information for the source for each calendar month:

   (a) the total quantity of coal burned (tons);

   (b) the average ash content (percent) of the coal burned;

   (c) the average sulfur content (percent) of the coal burned;

   (d) the average heat content (Btu/lb) of the coal burned;

   (e) the average sulfur dioxide emission rate (lbs $SO_2/10^6$ Btu actual heat input) from the coal burned; and

   (f) the number of hours the source was in operation;

   These monthly reports shall be submitted by the 15 day of each month an shall address the data obtained during the previous calendar month.

(CONTINUED)

7. Within 6 months prior to May 1, 1992, this facility shall conduct, or have conducted, an emission test(s) for this source in order to demonstrate compliance with the allowable mass emission rate for particulates. The emission test(s) shall be conducted in accordance with the test methods and procedures specified in OAC rule 3745-17-03.

   Not later than 30 days prior to the proposed test date(s), this facility shall submit an "Intent to Test" notification to the Regional Air Pollution Agency. The "Intent to Test" notification shall describe in detail the proposed test methods and procedures, the source operating parameters, the time(s) and date(s) of the test(s), and the person(s) who will be conducting the test(s). Failure to submit such notification for review and approval prior to the test(s) may result in RAPCA's refusal to accept the results of the emission test(s).

   Personnel from the Regional Air Pollution Control Agency shall be permitted to witness the test(s), examine the testing equipment and acquire data and information regarding the source operating parameters.

   A copy of a comprehensive written report on the results of the emission test(s) shall be submitted to the Regional Air Pollution Control Agency within 30 days following completion of the test(s).

8. In accordance with Permit to Install (PTI) 08-183, this source, B006, is subject to the following terms and conditions:

   a) The operation of this boiler shall be limited to 24 hours per day, 7 days per week, 40 weeks per year for a cumulative total of 6720 hours per year;

   b) The maximum operating rate of this boiler shall be limited to 160.0 million BTU per hour of actual heat input;

   c) Based on the operating schedule specified in condition 8a, the maximum allowable particulate emission rate specified in condition #3 and the maximum operating capacity specified in condition #8b particulate emissions International boiler #6 shall be limited 16.0 pounds per hour, 384.0 pounds per day 1.34 tons per week.

(CONTINUED)

d) Combined annual coal usage for the Wright Patterson Air Force Base, averaged over calendar years 1977, 1978, and 1979, was determined to be 101,000 tons of which 25,900 tons were burned in the existing boilers identified as Edgemoor boilers #1 and #2 (Building 20770) and Combustion Eng. Boiler #2, B & W boiler #3 (Building 31240);

e) In accordance with Ohio Administrative Code 3745-17-10, the maximum allowable particulate emission rate for the existing boilers identified in condition #8d is 0.17 pound per one million BTU of actual heat input;

f) The maximum allowable particulate emission rate for the new boilers identified as E. Keeler boilers #3, #4, and #5 (Building 20770) and International boilers #4, #5, and #6 (Building 31240) is 0.10 pound per million BTU of actual heat input.

g) Based on a heating value of 26 million BTU per ton of coal, the annual average coal usage data as specified in condition #8d and the maximum allowable particulate emission rates as specified in conditions #8e and #8f combined annual particulate emissions from the Wright Patterson Air Force Base coal-fired boilers (identified below) shall not exceed 155 tons:

Building 20770

OEPA Premise No.	0829700185 B001	I.D.	Edgemoor boiler #1
	0829700185 B002		Edgemoor boiler #2
	0829700185 B003		E.Keeler boiler #3
	0829700185 B004		E.Keeler boiler #4
	0829700185 B005		E.Keeler boiler #5

Building 31240

OEPA Premise No.	0829700199 B002	I.D.	Combustion Eng. boiler#2
	0829700199 B003		B & W boiler #3
	0829700199 B004		International boiler #4
	0829700199 B005		International boiler #5
	0829700199 B006		International boiler #6

h) Based on the operating schedule specified in condition, 8a, the maximum allowable sulfur dioxide emission rate specified in condition #3 and the maximum operating capacity specified in condition 8b,sulfur dioxide emission from International boiler #6 shall not exceed to 320.0 pounds per hour, 3.84 tons per day, 26.88 tons per week.

(CONTINUED)

i) Based on a heating value of 26 million BTU per ton of coal, an annual average coal usage figure (as recorded over calendar years 1977, 1978, and 1979) of 101,000 tons, and the sulfur dioxide allowable emission rate as specified in condition #3 combined annual sulfur dioxide emissions from the Wright Patterson Air Force Base coal-fired boilers as identified in condition #8g shall not exceed 2626 tons.

9. The facility is hereby notified that this permit, and all agency records concerning the operation of this permitted source are subject to public disclosure in accordance with OAC rule 3745-49-03.

Prepared By: Patricia L. Bradley
Date Prepared: April 23, 1990

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Vita

Captain Ken Smith was born on February 7, 1964 in Homestead, Florida. He graduated from Greenon High School in Springfield, Ohio in 1982. He attended the University of Cincinnati, graduating with a Bachelor of Science in Electrical Engineering in June 1987. He received his commission through the AFROTC program and began his military career at Luke Air Force Base in February 1988. While at Luke AFB, he served in the 832nd Civil Engineering Squadron as Chief, Utilities; Chief, Heavy Repair; and Chief, SABER. He was deployed in support of Operation Desert Shield/Storm from November 1990 until June 1991. He returned to Luke AFB after his deployment until entering the School of Engineering, Air Force Institute of Technology, in May 1992.

Permanent Address: 5213 Saum Street
Fairborn, Ohio 45324

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1993

3. REPORT TYPE AND DATES COVERED
Master's Thesis

4. TITLE AND SUBTITLE
A FEASIBILITY STULY OF BURNING WASTE PAPER IN COAL-FIRED BOILERS ON AIR FORCE INSTALLATIONS

5. FUNDING NUMBERS

6. AUTHOR(S)
Kenneth P. Smith, Captain, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology
WPAFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GEE/ENV/93S-16

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This thesis examined the feasibility of using waste paper derived fuel in coal-fired boilers on Air Force installations in an attempt to help solve air pollution and solid waste disposal problems. The implementation of waste paper derived fuel was examined from both a technical acceptability and an economic feasibility viewpoint.

Waste paper was found to be technically acceptable for use as fuel. However, waste paper has certain characteristics that may create problems during combustion and therefore further research is required. These problems include the possibility of increased nitrous oxide emissions, increased volatile emissions, dioxin and furan emissions, formation of hydrochloric acid, and the presence of heavy metals in emissions and ash.

A life cycle cost model was developed to determine the economic feasibility of implementing waste paper derived fuel. This economic feasibility is dependent upon the answers to the above technical problems, but a case study of waste paper derived fuel at Wright-Patterson AFB showed a sufficient economic benefit to probably compensate for additional costs associated with these technical problems.

14. SUBJECT TERMS
Municipal Solid Waste, Boiler, Coal, Waste Paper, Clean Air Act, Pollution Prevention

15. NUMBER OF PAGES
105

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL